Innovation in the Built Environment

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ANDREW DAINTY
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Construction Innovation

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Innovation in the Built Environment

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CONSTRUCTION, CIVIL ENGINEERING & BUILT ENVIRONMENT
Wiley-Blackwell
mmetcalfe@wiley.com

Construction Innovation

Edited by

Finn Orstavik
University College Buskerud and Vestfold
Norway

Andrew Dainty
Loughborough University
UK

Carl Abbott
University of Salford
UK

WILEY Blackwell

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About the Authors

Carl Abbott

Carl Abbott is Professor of Construction Innovation & Enterprise in the School of the Built Environment at the University of Salford and Director of the Salford Centre for Research & Innovation (SCRI) in the built and human environment. Carl's research interests include innovation in university-city regions and the sustainable delivery of housing. Significant research projects in which Carl has been involved include the EU funded 'INNOPOLIS', the Economic and Social Research Council Distributed Innovation Project 'The impact of environmental regulation on innovation in the housing sector', the Engineering and Physical Sciences Research Council/Électricité de France funded 'People Energy & Buildings' project on the uptake of microgeneration technologies in housing.

Catherine Barlow

Catherine Barlow is a Research Fellow at the University of Salford and was previously a researcher for a regional housing association. Catherine's research has primarily focussed on innovation and regulation in the context of UK housing. Catherine's PhD was on the impact of the Code for Sustainable Homes on UK housing. Since gaining her PhD, Catherine has developed her research interests working as a Research Fellow on projects concerned with low energy housing including the Greater Manchester Local Interaction Programme, Milesecure 2050 and the Innovative Retrofit of Housing.

Frédéric Bougrain

Frédéric Bougrain works as a researcher for the Economics and Human Sciences Department at the Scientific and Technical Centre for Building, University Paris Est in France. His research is concentrated on innovations in the building and construction industry, public–private partnerships, asset management in the social housing sector and energy-saving performance contracts. He previously lectured at the University of Orléans (France) where he defended his PhD thesis on innovation, small- and medium-size enterprises and the consequences for regional technology policy.

Mario Bourgault

Mario Bourgault has conducted more than a decade of research in the field of innovation and project management. He has held the Canada Research

Chair in Technology Project Management since 2004. He is also head of Polytechnique Montreal's graduate program in project management. His work has been published in a number of journals, including *Project Management Journal*, *International Journal of Project Management*, *R&D Management* and *International Journal of Managing Projects in Business*. In addition to his academic credentials, he spent several years in the field working as a professional engineer, and he maintains close ties with the industry as a researcher and expert consultant.

Lena E. Bygballe

Lena E. Bygballe is Associate Professor at the Department of Strategy and Logistics at BI Norwegian Business School, Oslo, Norway. She is also chair of the Centre for the construction industry in the same department. Her research interests are in the area of interorganisational relationships with particular focus on organisation, learning and innovation.

Andrew Dainty

Andrew Dainty is Professor of Construction Sociology at Loughborough University's School of Civil and Building Engineering. For the past 20 years, his research has focused on social action within construction and other project-based sectors, particularly the social rules and processes that affect people working as members of project teams. He has a particular interest in practice-based perspectives on innovation in construction and in the relationship between innovation strategy and the performance of project-based firms. Andrew is co-editor of the leading research journal *Construction Management and Economics*, a past chair of the Association of Researchers in Construction Management (ARCOM) and former joint coordinator of CIB Task Group 76 on Recognising Innovation in Construction.

Nathalie Drouin

Nathalie Drouin, PhD (University of Cambridge), MBA (HEC-Montréal), is the Associate Dean of Research and former Director of Graduate programs in Project Management, School of Management at Université du Québec à Montreal (ESG UQAM) and a professor, Department of Management and Technology, ESG UQAM. She teaches initiation and strategic management of projects in the Graduate Project Management Programs. Her research has been funded by the Social Sciences and Humanities Research Council of Canada, the Canadian Institute of Health Research, the Quebec Research Council, and the Project Management Institute. She is a Member of the Scientific Committee of the Project Management Research Chair, ESG UQAM.

Marianne Forman

Marianne Forman is Senior Researcher at the Danish Building Research Institute, Aalborg University, Denmark. Her research area encompasses innovation, user-driven innovation, sustainable transition, environmental management in companies and product chains, project management and change processes, working environment and cooperation inside companies and among companies.

She graduated from the Danish Technical University (1991), where she also defended her PhD thesis on Processes of Change and Participation Forms in Preventive Environmental Work (1998).

Martha E. Gross

Currently based in Arup's New York office, Martha Gross is a Senior Infrastructure Consultant with a focus on delivering transportation megaprojects. From her past and present roles as contractor, owner's engineer, and lender's advisor on highway and bridge projects up to $3 billion in construction cost, she has gained extensive first-hand experience with design-build and public-private partnership contracting. Among other recognitions she holds an MBA and PhD in civil engineering from Virginia Polytechnic Institute and State University, where her research focussed on infrastructure finance and delivery via PPP contracts.

Håkan Håkansson

Håkan Håkansson is Professor in International Management at the Department of Innovation and Economic Organisation at BI Norwegian Business School, Oslo, Norway. His research interests are in the area of interorganisational business relationships and business networks with particular focus on innovation and economic development.

Kim Haugbølle

Kim Haugbølle has been working closely with construction clients for almost twenty years, and he was instrumental in the establishment of the Danish Construction Clients Association in 1999. He is coordinating the CIB Working Commission on Clients and Users in Construction with Professor David Boyd. Kim has published extensively on innovation and technology assessment in the construction industry with special emphasis on procurement, sustainable design and life cycle economics. The academic insights have been turned into the development of a life cycle costing tool for the Danish version of the German Sustainable Building Council sustainability certification scheme.

J. L. (John) Heintz

Dr. John L. Heintz is Head of Section and Associate Professor in the Design and Construction Management Section of the Faculty of Architecture at the Delft University of Technology. Before pursuing his PhD in architecture at the Technical University of Delft, he earned his professional degree in architecture from the University of Calgary, graduating with the AIA Gold Medal. His research interests include the strategic management of architectural firms, new forms of architectural practise, design collaboration, design quality and knowledge sharing in design projects. He is co-author of *De Architect in de Praktijk* (in Dutch).

Malena Ingemansson

Malena Ingemansson is post doc at the Centre for Science and Technology Studies at Uppsala University. Her research interests are in the area of technology development and innovation involving settings such as industrial production and academia.

Kristian Kreiner

Kristian Kreiner is professor at Copenhagen Business School, Department of Organization. He was the founder and director of the Centre for Management Studies of the Building Process (www.CLIBYG.org). In his research, he aims to understand how things are organized under conditions of complexity, uncertainty and ambiguity. These interests have occasioned detailed empirical studies in many sectors and industries, not the least in construction. Current studies include research on the ways in which we manage to make difficult or impossible choices, for example in connection with architectural competitions.

Heli Koukkari

Heli Koukkari is Principal Scientist at the VTT Technical Research Centre of Finland, which she joined in 1982. Her R&D topics have covered overall performance and sustainability of buildings; concrete, steel, composite and timber structures and most recently innovation processes. She has been vice-chair of the COST Action C25, Sustainability of Constructions – Integrated Approach to Life-Time Structural Engineering, and member of the RTD Committee of the European Network of Building Research Institutes ENBRI; of the TC14 Sustainable and Eco-Efficient Steel Construction of the European Convention for Constructional Steelwork ECCS; and of Work Group3, Construction & Infrastructure of the European Steel Technology Platform ESTEP.

Graeme D. Larsen

Graeme D. Larsen is Lecturer in Construction Management and the School Director of Post Graduate Research Studies, University of Reading. His research interests are wide reaching, from innovation diffusion to competitiveness networks of small- to medium-size enterprises. He is actively engaged with the Chartered Institute of Building, being an academic and industry membership assessor. His more recent research focused on corporate social responsibility, use of communication networks, innovative procurement methods in niche markets, sustainability and resilience planning.

Gonzalo Lizarralde

A specialist in planning, management and evaluation of international architecture projects, Gonzalo Lizarralde is a professor at the School of Architecture at the Université de Montréal. He has fifteen years of experience in consulting for architecture and construction projects and has published numerous articles in the fields of low-cost housing and project management. Dr. Lizarralde has been awarded research grants and scholarships from the National Research Foundation of South Africa, the Canadian and Quebec governments and other funding agencies. Dr. Lizarralde is director of the IF Research Group, which studies the processes related to the planning and development of construction projects.

Martin Loosemore

Martin Loosemore is Professor of Construction Management at UNSW, Sydney, Australia. He is a Visiting Professor at The University of Loughborough, UK, and a Fellow of the Royal Institution of Chartered Surveyors and of the Chartered Institute of Building. Martin was an advisor on international workplace productivity and reform to the Australian Federal Government's 2003 Royal Commission into the Building and Construction Industry. He served for six years on the Australian Federal Government's Built Environment Industry Innovation Council advising on Australian Government innovation policy.

Karen Manley

Karen Manley is a researcher in the area of innovation in infrastructure projects. She is currently Associate Professor, Science and Engineering Faculty, Queensland University of Technology and Higher Degree Research Director, School of Civil Engineering and Built Environment. She has many years of experience as an academic and private consultant, specialising in the application of post-neoclassical approaches to the analysis of innovation and industry growth. She investigates knowledge flows, networking and innovation systems to shed light on the performance of a number of industries, including the construction industry. Her current research focus is on innovative approaches to collaborative procurement and sustainable building. She has published extensively in international journals, and her work has informed the development of government policy across Australia in the area of innovation capacity.

R. Edward Minchin Jr.

In a twenty-nine-year career in industry and academia, Dr. Minchin has worked as a contractor's unskilled labourer; contractor's cost estimator; highway, bridge and drainage designer; owner's inspector; owner's field engineer; transportation agency executive; lecturer; researcher; and arbiter. Since obtaining his PhD (Pennsylvania State University, 1999), his research has resulted in over 95 publications with recent emphasis on project delivery systems, especially CMGC and DB. He currently holds the Rinker Professorship and serves as Director of Master's Programs at the M.E. Rinker Sr. School of Construction Management at the University of Florida. In his role as arbiter, he currently sits on six Disputes Review Boards.

Finn Orstavik

Finn Orstavik has his doctoral degree in sociology from the University of Oslo (1996). He is specializes in innovation studies and has early in his career done historical studies of military research and development and private sector innovation in digital computers in Norway. His later research covers empirical and historical studies of industry development, the institutional system of innovation and innovation policy. His theoretical interests span Giddens' structuration theory, general systems theory, Luhmann's theory of social systems, innovation theory and American pragmatist philosophers (e.g. Dewey, Mead, Follett). He has studied innovation and knowledge processes in the construction industry over a period of 10 years and has published studies amongst others on industrial clusters, innovation systems and innovation in Norwegian house building. Orstavik has been Research Director of the Centre for Regional Innovation and teaches master level courses on Innovation and Leadership and Innovation and Globalisation at the University College in Buskerud and Vestfold in Norway.

Timothy M. Rose
Timothy M. Rose is a Lecturer in the Science and Engineering Faculty at Queensland University of Technology and a Course Leader of the Master of Project Management and Master of Infrastructure Management courses at this university. Prior to this appointment, Tim worked as a senior project manager on major construction projects in Australia. His multidisciplinary research has contributed to both construction project management and broader business management in project based-industries as the presence of his research in journals across these fields has demonstrated. He has published more than twenty peer reviewed articles and book chapters in the areas of procurement, sustainability and innovation, and has a strong research interest in applied economic and psychological-based models that predict motivation, commitment and performance across complex construction supply chains.

Martin Sexton
Martin Sexton has been Principal Investigator and Co-investigator on numerous Engineering and Physical Science Research Council, Economic and Social Research Council and European Commission awards totalling in excess of £7 million. He is recognised internationally for his research in the area of innovation management, particularly in the contexts of small construction firms and knowledge-intensive professional service firms. Martin is currently focusing on transition management for sustainability, environmental innovation, energy systems and the impact of regulation on innovation. Martin was formerly the Joint Co-ordinator of the CIB Working Commission 65 – Organisation and Management of Construction.

Laurent Viel
Laurent Viel is a PhD candidate at Université de Montréal. He has been affiliated with the IF Research Group since 2012. His research examines the ethical considerations of collaboration and participation processes in urban projects. Since 2013, he works with a municipality in France.

J. W. F. (Hans) Wamelink
Hans Wamelink is Professor of Design & Construction Management and Head of the Department Real Estate & Housing at the Faculty of Architecture, Delft University of Technology. His main focus is on cooperation in the supply chain, new ways to contract and process innovation. Previously he worked for ten years as part-time Assistant Professor at the Faculty of Technology Management of Eindhoven University of Technology. He has also gained substantial experience in practise as the owner and managing director of a management and consultancy firm.

Foreword

Members of the CIB community worldwide are proud of the contribution that they collectively make to creating and maintaining a better built environment. They are aware of the challenges that the construction industry faces and the important role that innovation plays in realising powerful solutions. Nevertheless, despite the strong interest, agreeing on a simple definition and an approach to measuring innovation remains elusive. CIB members may feel that the innovation construct is both complex and nebulous, and disagree about questions as fundamental as whether the industry is innovative or not. However, one thing that all agree upon is that we need to know more about the innovation phenomenon. It was for this reason that I was keen to endorse the idea of creating a CIB Task Group titled 'Recognising Innovation' in Dubrovnik in 2009.

During its lifetime the group and its members were a vibrant presence at CIB events. Amongst other activities, they hosted debates, conducted scenario workshops and ran special paper tracks. Not least importantly they announced the idea of publishing this book. Here they have coalesced many of the perspectives emerging through the efforts of the group, along with those of other leading scholars in the construction innovation field. The result is a presentation of an eclectic and informative set of perspectives that sheds light on innovation and its importance in realising our aspirations for the built environment.

On behalf of CIB and our membership, I am very pleased to endorse this publication. It is a thought-provoking and valuable contribution to research on innovation in the built environment. I am confident that it provides important insights for anyone wishing to understand, to do research on or to effectively manage innovation in or adjacent to the construction sector.

Dr. Wim Bakens
Secretary General, CIB

Preface

The origin of this book lies in the work of an international collaborative task group convened by the International Council for Research and Innovation in Building and Construction (CIB), and the development of ideas have been enriched by a research project on knowledge processes in construction carried out through the years 2007–2012 with financing from the Research Council of Norway and industry partners. The CIB Task Group 76 explored the ways in which innovation was recognised and measured in the construction industry. It brought together diverse perspectives on innovation in the built environment in order to understand the multiple ways in which the term has been mobilised and deployed in construction research and practice. Over three and a half years, the group provided a forum for critical debates, workshops, and special paper tracks, through which a range of divergent meanings and implications of innovation were revealed. This book coalesces some of these perspectives with those of other scholars within the construction innovation field. It has been written to stimulate new debates in construction innovation within the research and practice communities and to inspire reflection on the ways in which innovation can be considered and ultimately capitalised on for the benefit of organisations and society at large.

As the editors of the volume, we wish to thank all the excellent scholars who have contributed to the book in such a positive and insightful way. We also wish to thank our friends in Wiley Blackwell who have encouraged and supported this project all the way from inception to completion. We hope that this book provides some thought-provoking insights that will inspire future research and scholarship into the ways in which we study, recognise, and encourage innovation within the construction sector.

Finn Orstavik, Andy Dainty and Carl Abbott
May 2014

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Introduction

Finn Orstavik, Andrew Dainty and Carl Abbott

Historically, two very different and yet inseparable impulses have shaped modern business: a quest for more efficient production and the pursuit of competitive advantage through novelty and innovation. Production is typically carried out in enterprises whose survival depends on offering goods and services for which alternatives may be available from a range of competing suppliers. To survive and flourish under such circumstances, enterprises have to make efforts, for example, to reduce prices (by avoiding waste and increasing productivity) and/or to create novel value propositions (by innovating). Although these fundamental agendas are certainly not mutually exclusive, embracing innovation encompasses much more than addressing production and distribution inefficiencies. In his early theory on economic development, the Austrian-American economist Joseph A. Schumpeter suggests that what really counts is the competition from new commodities, new technology, new sources of supply, and new types of organization (Schumpeter 1983). Unlike gradual efficiency improvements, he reiterates in a later work, that innovation 'strikes not at the margins of the profits and the outputs of the existing firms but at their foundations and their very lives'. If price competition is comparable to forcing a door, then innovation is more like bombardment, he proclaims (Schumpeter 1976).

However, to succeed in *realizing* innovations is difficult, 'first, because they lie outside of the routine tasks which everybody understands' and 'secondly, because the environment resists in many ways that vary, according to social conditions, from simple refusal either to finance or to buy a new thing, to physical attack on the man who tries to produce it' (Schumpeter 1976). Even though Schumpeter saw that innovation-based competition was becoming institutionalised as 'technological progress is increasingly

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becoming the business of teams of trained specialists who turn out what is required and make it work in predictable ways', he still maintained that the resistance to innovation based on economic interests vested in the established order would never go away (Schumpeter 1976). Accordingly, when considering construction and the production of the built environment in modern societies, he in the same text noted that vested interests and the weight of tradition in a very significant way stifled innovation, representing 'the great obstacle on the road toward mass production of cheap housing which presupposes radical mechanization and wholesale elimination of inefficient methods of work on the plot'.

As pointed out by Loosemore in Chapter 5 in this volume, a simple linear model of innovation has often dominated thinking about construction innovation in public policy, in academic institutions and in industry organizations and firms. In this linear model, results from scientific research and technological development are supposed to feed into commercial activities and drive industrial development and growth (Stokes 1997). This model of innovation is seen by many as inextricably linked to Schumpeter's theories and his notion of the entrepreneurial function in capitalist economies (Pavitt 2005). Arguably, this model forms a set of implicit premises when it is contended that the construction industry has a troubled record of innovation for growth and competiveness. This is a recurring theme in the literature on construction. The problem is seen as a lack of willingness to adopt novel results from scientific research and technological development, and even more generally, an inability or unwillingness to learn (e.g. Egan 1998; Lepatner 2007).

Several recent contributions have, however, problematized this view and have pointed out the importance of recognising the varied nature and effects of innovation. For example, in their comprehensive work on the management of innovation, Tidd and Bessant (2013) espouse a process view of innovation, one of 'turning ideas into reality and capturing value from them' (p. 21). They see innovation as far more than the generation of new ideas. Innovation also encompasses the need to carefully select the ideas with potential, to implement them and to capture value from them. Process-oriented research on innovation, such as documented in contributions by Van de Ven et al. (1989, 1999), also shows that innovation does not follow linear pathways and is generally marked by ambiguity and discontinuity. Innovation is often very costly in part because organizations have to reframe their approach to reflect the new circumstances that result from the innovation efforts themselves. Beyond this, innovators and those affected by innovation will also learn to anticipate effects. Hence, reflexivity enters into innovation processes, which means that actions and decisions can be understood only contextually and in a temporal framework. All this serves to emphasise the need to consider innovation as a complex phenomenon and to develop alternatives to the simple linear model that has dominated much of the innovation discourse. Much remains before innovation in construction is adequately understood, and so different standpoints and models should be explored in research.

Construction Innovation: Concepts and Controversies

The doubts found in some of the research literature regarding the validity of the broad generalization that construction sector stakeholders are reluctant to innovate and to learn new and efficient ways of building (Winch 2003; Abbott et al. 2007; Whyte and Sexton 2011) does not overshadow the overall impression created by industry experts and policy-makers that it is the culture and/or the structural composition of the industry that explains its reluctance to innovate. This perception is compounded by the sector lagging behind other sectors when measured against traditional innovation metrics (NESTA 2007) and commentaries on innovation found within sector reform reports. The most recent UK report – the *Industrial Strategy for Construction* (BIS 2013) – suggests that around two-thirds of construction contracting companies fail to innovate. Indeed, aspects of the production of the built environment have been referred to as 'backwards' (Woudhuysen and Abley 2004) and parts of it even as 'degenerate' (Silber 2007). It may be that since Schumpeter himself made known his views on the challenges of innovation in the construction and building sector, a suspicion has lingered that the industry is in the grips of particular stakeholder interests that uphold the status quo at the expense of the industry as a whole and of society. It would seem, therefore, that significant challenges remain in terms industrial organization and innovation (Manseau and Seaden 2001).

Signs of insufficient performance in the construction sector are not hard to find, with quality and safety problems, numerous bankruptcies and projects often running late and over budget (Flyvebjerg, Bruzelius, and Rothengatter 2003; Williams 2005). Similarly, there are examples of practices that endure virtually unchanged over years in spite of obvious issues with quality and performance and of indications that compliance with minimum quality requirements in building codes is routinely treated as 'best practice' by constructors (Orstavik 2014; see also Chapter 6 in the present volume). Still, novel materials, new business models and new ways of designing built objects are emerging, demonstrating that much creative problem solving and local innovation is actually going on in the sector. Also, tangible results of much creative work remains hidden inside projects and fails to translate across other projects and diffuse more widely (Dubois and Gadde 2002; Abbott et al. 2007). As has been pointed out by Slaughter (1993, 1998, 2000), successful innovation requires a deeper consideration of the social and organizational contexts in which it is located. Such complexity renders the evaluation and quantification of innovation in construction difficult, so traditional metrics such as research and development (R&D) expenditure and patent rates are arguably poor proxies for the actuality of innovation in the sector. Also work by both NESTA (Halkett 2007) and Barrett et al. (2007) has suggested that innovations in service provision or microlevel project innovations developed through interactions between construction companies, consultants and clients are often not picked up by others. What emerges here, again, is a highly complex and contested arena both for defining innovation and for establishing appropriate metrics, and one that demands a plurality of different perspectives if it is to be understood within the multiple and diverse contexts that make up the construction sector.

Perspectives on Construction Innovation

In trying to open up a more pluralistic perspective on construction innovation, we have sought to include in this volume contributions that mobilise theoretical frameworks as structuring devices or as lenses necessary to bring forth productive interaction and reflection between differing positions. The point here is that we have sought to avoid privileging any particular position over others, instead making clear that concepts can be understood differently. This being said, there are some important points of departure that underpin the contributions of this text. First, we contend, much as Schumpeter did in his early theory, that innovation should be considered more than a purely economic phenomenon. Second, an essential feature of innovation is that it is maintained through dynamic value creation efforts. In fact, innovation can be defined as humanly created changes in established approaches to value creation. We prefer using the term *value creation* rather than *production*, to avoid narrow interpretations of this term. However, the term *value creation* will often be synonymous with the term *production* in discussions and theories about innovation. A third underpinning consideration is that value creation invariably concerns human work, combining diverse elements into 'new combinations'. These are not necessarily 'things' in the sense of tangible objects but anything that human beings care to combine into entities because they think these have value of some kind. 'New combinations' is, of course, a term also used by Schumpeter, and we agree with Drejer (2004) that there is nothing in Schumpeter's theories that reduces innovation solely to concerning physical objects or processes related to producing such objects. Thus, innovation is in this volume seen as humanly created changes in *established ways of creating value*, whatever it is that is made and whatever this value consists of. What is created and consumed does not need to be material, but if we are to speak about innovation, change has to be effected in the way value is created, and this change must be seen by particular stakeholders as meaningful. And it must in some way be lasting (or sticky) because creating a novelty (for instance a technical invention or a novel architectural design for one building) that does not enter into a practice, is not used in other contexts and does not in any way diffuse cannot in itself be innovation. This follows from our definition of innovation itself because it identifies innovation as *changes* in established ways of value creation. Both the 'established ways' and the 'novel ways' resulting from innovation are institutionalized and, hence, to some extent lasting (Orstavik 2014). However, and as a matter of course, the timespans for which innovations are actually relevant will vary to a great deal.

Elements of these underpinning characteristics can be traced throughout the contributions contained within this volume and in the way the chapters are organized. Each chapter is intended to provide a different viewpoint on innovation in the built environment and to challenge some conventional way of thinking about construction innovation. Among the most widely diffused common-sense assumptions about innovation is that it is profitable and that the fundamental driving force for innovation is the economic gains that innovation brings. In Chapter 2 on incentives for innovation, **Finn Orstavik** challenges such assumptions. He argues on the basis of Schumpeter's perspective on innovation that even though innovation is a decisive factor in competition between firms, innovation is much more than an economic phenomenon for these firms. Actually, innovation is the outcome of actions and decisions that are of a different kind than those recognized as economic and rational. In fact, the gains from innovation are highly uncertain; therefore, innovation is more like a lottery than it is a normal investment in expansion of an existing business. For Orstavik, it is essential to understand reasons for innovative behaviour in construction and therefore *not* to jump to conclusions about motivations. For example, one should certainly not simply assume that stakeholders are irrational when they decide to avoid investing in innovation. Observers have to ask, rather, what it is with construction that makes it less enticing to play the lottery of innovation there than in other industrial sectors. The answer, Orstavik argues, is found in the ubiquitous presence of asymmetric information in building activities and in the fact that construction production involves the creation of bespoke complex and dynamic systems. The specific form of production dominant in building entails multi-parametric optimization, not limited to the establishment of a novel line of production, but integrated into the actual production operations themselves. The complexity of building operations and design makes multi-parametric optimization essential and unavoidable. This is a fundamental reason that innovation is less appealing in the construction sector than in many other sectors.

Multi-parametric optimization is also at the heart of **Kristian Kreiner**'s contribution in this book. In Chapter 3, he examines a particular case, a construction project that was aimed at producing *the world's most accessible office building*. Considering the value aspect of innovation, Kreiner finds that the aim of this project in itself represented an ambition for carrying out an innovative building project. The innovative content could not, however, be clearly defined in terms of the resulting building being more accessible than any other building. It proved impossible to operationalize this concept because accessibility is multidimensional and it depends to such an extent on the enormous diversity of human wants and needs. The task of creating the world's most accessible building involved an effort in multi-parametric optimization with no clear solution. What the project did contribute, however, and what was a genuine novelty in the approach to creating value (a new building), was not a new technical system or a new architectural design, but rather the way the building design process was conceptualized. This concerned both the *rationale* and the *modus operandi* of the design process. Rather than creating a single, optimal, or nearly optimal design for the building, the solution was to conceive of the building and its users as a 'living ecology'. Rather than being a fixed structure with assigned meanings, the building was to be seen as a living ecology where meaning would be continually created by the users. In this project, therefore, the essential innovation – if what has been developed is actually carried over into later projects and in this sense is sticky – is the changed way of thinking about design in the design work and in the overall building process. In his fascinating story, Kreiner draws attention to both the inherent difficulties in determining the qualities of a product and the fragility of the conditions that shape the eventual material outcome. He also sensitizes us to the ambiguities that can face us when trying to determine the actual value of an innovation. In this case, what is created is a larger space for human beings to creatively contribute to the making of meaning in their own life worlds in interaction with the material and social realities surrounding us.

These issues resonate across many of the chapters that follow, and not least with the subsequent Chapter 4 by **Gonzalo Lizarralde**, **Mario Bourgault**, **Nathalie Drouin**, and **Laurent Viel**. In their text, the authors are concerned with what they see as an overly restricted vision of value and of what construction innovation is about in general. A stakeholder perspective on construction innovation is mobilized, and the argument is made that more stakeholders ought to be involved in building and in design. Rather than sticking to a narrow – statistical – understanding of what is to be counted as construction, many more activities have to be considered as relevant. In general, all those involved and affected by innovation in the built environment should be considered stakeholders and ought to have a say in these processes. Also, the value of innovation cannot be considered only in terms of added value and profitability realized by construction firms. A broader understanding of value, resulting from interest articulation and negotiations among stakeholders, is essential for the ability to organize innovation in the built environment in good ways. Also, there is an urgent need to understand that *integration champions* are essential in innovation in the built environment. Champions are often aiming for quite different things than economic profit. Instead, they are working to integrate stakeholders and facilitate stakeholders' active involvement and the champions are as such essential both for innovation in the built environment and for our ability to understand what innovation in the built environment and in construction is fundamentally about.

Stakeholder involvement is a theme discussed further by **Martin Loosemore** in Chapter 5. As mentioned earlier in this introduction, Loosemore questions the linear model of innovation, which he sees lifting its head much too often in discussions about innovation in construction and when the challenges facing the industry are debated. Innovation should not be conceived of solely as an outcome of scientific research and technology development and the discussions about construction innovation should not simply be on the transfer of technology or the ability of firms to learn and their willingness to innovate. Construction firms have to continually renew themselves and their mode of doing business, given the demanding realities of innovation based competition. The source of novelty for this kind of competition is more often than not the creativity and collaborative potential of people doing project work. Loosemore raises the questions to what extent innovation actually can be planned and managed and to what extent innovation is rather an emergent phenomenon originating in the creativity of and the collaboration between those people who are themselves involved in the construction projects. Loosemore proposes to adopt a grassroots perspective on innovation and draws attention to some important recent contributions to innovation theory, amongst others targeting service provision industries and aiming to supersede conventional innovation analyses anchored in a view of economic growth as based on the expansion of efficient volume production of standard products.

The non-linearity of innovation processes is a theme further developed by **Carl Abbott**, **Martin Sexton,** and **Catherine Barlow** in Chapter 6. These authors are also interested in the role of stakeholders in construction and construction innovation and have used a socio-technical network perspective to analyse how decisions are made on adopting sustainability-related innovations, such as micro-generating technology in new build housing. Several case studies have been performed that have given novel insights into the complex ways in which technology, regulation and organizational processes combine to shape the innovation context. In the chapter, an illustration based on one of these case studies is used to show that innovation can be triggered by regulation but that outcomes often do not necessarily reflect ultimate policy objectives in an effective way. The adoption of an innovation is decided through a recursive process of interest articulation and negotiations, and the fundamental impulse for innovation comes from above such as from regulations formulated on the national level. The outcome – the innovation – can end up being a compromise that does not, or only partially, fulfil needs of stakeholders. Policy aims can be stifled and the diffusion of innovation inhibited due to the entirely logical behaviour of actors with misaligned needs.

We have seen that two strikingly diverse perspectives are developed in Chapter 5 and 6. The former proposes a bottom-up view, the latter a top-down perspective on what triggers – or should trigger – innovation in the built environment: grassroots initiatives versus state-imposed regulations. For those feeling the urge for moving towards a synthesis between the two, potentially useful conceptual resources and arguments are found in Chapter 7. Here, the authors **Lena Bygballe, Håkan Håkansson and Malena Ingemansson** present an industrial network perspective on innovation. They acknowledge the many interdependencies necessary for realising innovation and the involvement of many stakeholders located along the value chains of building. Furthermore, they call attention to the fact that the realities of construction innovation are consistent with the important general point made by Schumpeter (1983) in that resources necessary for innovation most often are committed to entirely other purposes. This means that innovation cannot but be disruptive to some extent, and this nearly always creates significant obstacles. Innovation can be successful only when new or different interfaces are created between technical and organisational resources. Innovation is driven forwards by way of interaction and adaptation processes between actors and their resources. This close interaction involving learning, long-term relationships, and trust is not compatible with basic neoclassical market models, has obvious and important implications for any attempt to formulate effective innovation policy, and for companies' own structuring of their innovation efforts.

Graeme Larsen further explores the realities networks in construction innovation in Chapter 8. His focus is not so much on the first creation of novelties as it is on the diffusion of innovations, and the transformation of innovation taking place as they are diffused to ever-new firms. Larsen is interested in the large number of small and medium sized constructors in the UK industry, and presents an interpretive analysis of a large data set on network linkages. The data is analysed with the help of social network analysis software, and graphic illustrations provide a rare view into the complex realities of networks that actors in construction are embedded in. Actors are part of dynamic networks through which innovations are shaped, changed and contested over time, albeit not in isolation of the immediate surroundings nor unaffected by broader institutional forces. Networks inside and outside organizations are visualised, hence, the discussion regarding the nature of industrial innovation networks in Chapter 7 is complemented and increases our understanding of just how ubiquitous such networks are. An important policy implication highlighted by the author is that efforts to promote diffusion of innovation must be context specific and localized, rather than based on generic best practice initiatives, if they are to be effective.

Another take on innovation networks and collaboration is developed by **Kim Haugbølle**, **Marianne Forman** and **Frédéric Bougrain** in Chapter 9. Here and similar to Chapter 11 later in this volume, the focus is not on the networks as such, but on the specific role played by clients in the context of innovation. An analysis is presented that details the ways clients can influence innovation – in their role as stakeholders: as producers, as users or as intermediaries. In a similar way as in Chapter 6 that discussed the intricacies of deciding on employing micro-generation technology, the authors of Chapter 9 point out that innovation is realized not by individual people acting on their own, but through complex interactions among actors and technologies that together can be seen as forming dynamic socio-technical systems. Indeed, moving close to the idea of grassroots driven innovation (Chapter 5) regarding the actual sources of innovation, the authors find that clients often are closely involved in innovation development, and they are found to be effective in promoting all kinds of innovation: not only novel products but also innovative processes and organizational and market innovations.

All of the chapters in this volume from Chapter 4 through to Chapter 9 are concerned fundamentally with different types of actors, their role as stakeholders, and the complexities of their linkages and interactions in innovation. Abbott et al. in Chapter 6 concentrate attention on the effects of policies and policy instruments while maintaining the focus on actors. In this way, the authors introduce the institutional arrangements into the analysis in a way that goes beyond the idea that individual actors are integrated in networks.

In Chapter 10, without departing fully from the established track, authors **Timothy Rose** and **Karen Manley** emphasize even more than Abbott et al. the significance of institutional arrangements for innovative behaviour and decision making. Rose and Manley's point of departure is comparable to that also formulated by Larsen in Chapter 8, and by Wamelink and Heintz in Chapter 11: namely, that innovation in construction generally happens through diffusion. In Chapter 10, Rose and Manley are concerned with the adoption of innovative building products, not so much the decision-making processes in which adoption is effected, but how institutional frameworks impact on such processes. Their analysis is based on earlier research, specifically on a focus group-based study of industry experts' views on conditions for adoption of novel construction products in Australian road building. The aspects of the institutional framework that the industry experts themselves draw attention to are first and foremost narrow project tendering practices, and the difficulties in making clear the actual risk distribution across stakeholders. The experts suggest remedies such as up-front product certification, performance-based specifications, innovation performance assessment (after the construction project that contains an element of innovation is concluded) and finally that trust is developed between relevant stakeholders (product suppliers and road asset operators in particular) for example through prior collaborations in the context of other in projects.

Chapter 11 by **Hans Wamelink** and **John Heintz** represents a similar interest in innovation as adoption and as diffusion as in earlier chapters. Also, these authors are concerned with institutional arrangements. This time, however, these arrangements are not seen as a surrounding context, but as a property of the industry itself. The authors do not dispute the significance of networks, but argue that fragmentation and dis-connectedness are prominent features of the industry structure, and that this represents major obstacles to construction project performance. Rather than deploring the fragmentation's possible negative effects on innovation, they turn the issue around and propose that what we should be concerned with is not innovation per se, but innovation as an essential instrument in efforts to reduce the detrimental effects of industry fragmentation. Certainly, not all innovation is essential in this perspective. The authors discuss three forms of innovation, all technology based and all driven by demanding clients. Over the last years in the Netherlands, the experience is that in order to satisfy their clients, leading construction firms have been driven to further the integration of stakeholders in their projects. The three ways this has been done are through integrated project delivery, by way of building information modelling and through supply chain integration. All these are major strategies by which technological innovation can be used to promote a tighter coupling of firms and other organizations, and ultimately a better performing industry. The key to all this is seen by Wamelink and Heintz as the demanding client.

In Chapter 12 **Edward Minchin** and **Martha Gross** are also concerned with the demand side in their analysis of innovation in road building, this time not in Australia, but in the USA. While client demand for innovation is recognized as a key determinant, Minchin and Gross reintroduce the institutional framework as a structure shaped by policy, and see innovation as a 'dependent variable'. They argue that the structure of delivery systems is essential for the propensity of builders to incorporate the use of innovative building products, and for their willingness to engage in other kinds of innovation. Based on several case studies, the authors find indications that some types of structural business arrangements are much more conducive to innovation than others. Specifically, 'design-build' (DB) and 'construction-manager-as-general-contractor' (CMGC) are configurations of delivery systems that promote innovation, while 'public-private-partnerships' (PPP) seem not to have the same effect.

In the final contribution to this volume, in Chapter 13, **Heli Koukkari** and **Finn Orstavik** take up the discussion concerning innovation for sustainability in construction, which was analysed also in Chapter 6. As the lead author, Koukkari has been able to draw on her earlier research on developments in the industry and in policy in Finland. The argument is made that construction products have huge impact on the ways the built environment is produced, used and maintained. It is quite surprising that despite the obvious significance of physical products for the environmental footprint of construction, innovation activities of construction product manufacturers are seldom investigated in their own right. Today, global environmental concerns, not least the climate challenge, accentuate the need to understand determinants of product innovations. In the chapter, the authors explain how a study was conducted in Finland to explore more in depth how manufacturers perceive and respond to societal concerns, and to related market challenges. A multiple case study was conducted, and historical data on product innovation processes of ten manufacturers gathered. The key findings are that environmental issues have gradually grown from weak global signals towards market and regulation-based drivers in Finland. Energy-efficiency has been the single most important impetus that has resulted in a multitude of product modifications and novel products. On the national level, policy for furthering the construction industry has been transformed from a largely technology-driven and linear policy (compare the discussions in Chapter 4 and 5), to a broader systems orientation for sustainable development of the industry. Increasingly, technological opportunities have come to be seen in the context of medium- and long-term needs for development. This holds not only on the level of national policy, the authors argue, but also on the level of firms and their organisations: Innovation activities of firms are increasingly motivated and rationalized as efforts to develop technological and commercial solutions compatible with the emerging 'green' economy. This is not the result of any irrational idealism, but of a combination of real policy frameworks and incentive schemes on the one side, with outlooks and modes of thinking among industry leaders on the other.

Instead of Conclusions

It would be at odds with the whole purpose of the present volume to draw firm conclusions on the basis of the diverse arguments presented throughout this volume. The key themes and theoretical perspectives of each of these chapters have been outlined briefly in this introductory chapter, and in bringing the perspectives together in this way, we have tried to illustrate how the multiple perspectives on innovation taken by the chapter authors are connected at some points, but also that they are different in important respects.

We have used this review of the contents of this book to draw particular attention to the different ways in which the concept of innovation is used in the literature on construction innovation. It has been our goal to show that it is possible to define the concept of innovation in a clear and general way, without limiting the scope of the debates on innovation in construction. Also, we have wanted to show that there are multiple actors who come together around innovation, and that innovation outcomes that result also are multidimensional. Even though many think of innovation as the gradual diffusion of advanced technologies originating in research laboratories and in science, this aspect of innovation provides only a partial picture, and may be one that is not very representative.

Above all, what emerges throughout this volume is a picture of innovation as a largely emergent, non-linear, multi-level and hence, highly complex phenomenon. We have seen this complexity and the contested nature of the debates as to how this phenomenon should be understood in the construction literature, as a trigger for mobilising multiple perspectives on innovation in the built environment. Indeed, it was the recognition that this discourse encompasses what appear to be multiple, often opposing and yet seemingly valid perspectives, that provided the inspiration for the work with this book. It is our hope that it will act as a trigger for more analysis and further debate, and that it can be effective in promoting more nuanced views and more constructive future debates on innovation in the sector.

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2

Incentives for Innovation in Construction

Finn Orstavik

Introduction

Social and economic progress is achieved principally through the advancement and application of knowledge, according to the International Bank for Reconstruction and Development (World Bank 2002). Observing construction sites around the world, everyday building practices appear to be rooted in tradition, depend on cheap and unskilled work and provide poor working conditions and career prospects. This face of construction is, of course, most ferociously displayed in poor, developing countries. But claims have been made also that in rich, industrialized countries, the construction sector tends to be stagnant and inward looking, reflecting vested interests rather than the needs of an emerging knowledge society (Lepatner 2007). The question of *what is wrong with construction* has been posed both in construction research and in policymaking, and one perception has arguably marked the debate in particular. This is that stakeholders in construction need to wake up to the challenges of modernity, embrace innovation and realize that novelty and change is the only certain way for firms to prosper.

As pointed out in the introductory chapter of this volume, the time is ripe to sidestep this debate. Reframing the issues involved can give new insights and a better foundation for understanding what is actually going on in the processes through which the built environment is created. It is useful to think through one more time what innovation in construction entails rather than to continue making arguments based on all the standard assumptions. Among these is the contention that construction innovation has to be pursued as part of every firm's striving to create a profit.

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In this chapter, the re-examination commences by looking back and considering what Schumpeter's theory of economic development actually was about (Schumpeter 1983, 2006). In line with other classical economists, Schumpeter, an Austrian-American economist, saw economic production as the creation of utility and involving specialized human labour in operations of a repetitive nature. He conceived of innovation as the sticky (irreversible) transformation (qualitative change) of these basic value creation efforts. Schumpeter's overarching proposition was that innovation has been the driving force behind growth and increasing wealth in the world since the industrial revolution (Schumpeter 1982, 1983). Innovation theorists and economic historians have since done extensive research that confirms this claim: The global economy has continued to grow because of on-going and innovation-based competition (e. g. Rosenberg and Birdzell 1986; Landes 2003; Teece 2013). National and regional economies, as well as industrial sectors and industries, are being transformed through innovation. This broad trend certainly encompasses the construction sector, but many observers believe that there is a huge potential for further innovation and that this can come to change completely the face of this vast and very important part of modern economies (Manseau and Shields 2005; Newton, Hampson and Drogemuller 2009; Atkin and Borgbrant 2010; Akintoye, Goulding and Zawdie 2012).

This chapter aims to reveal two key insights: First, the overall pattern of growth created by innovation does not translate without problems between the aggregate level to the level of individual people and organisations. The significant growth effect of innovation-based competition on the macro- and meso-levels must not be allowed to obfuscate our understanding of the clear conclusions drawn in research into ongoing innovation processes (e. g. Hendry 1989; Van de Ven, et al. 1989; Bijker 1995; Van de Ven et al. 1999) and by quantitative assessments of success rates (such as Audretsch 1995) that for single firms, that is on the micro level, innovation is risky and very often unsuccessful.

Second, the nature of value creation activities taking place as the built environment is created are such that commercial benefits from innovation are smaller and further apart in construction than in some other industrial sectors. No doubt, there are industries wherein technological change is rapid, innovation is something that cannot be eschewed and potential rewards are significant. Examples of firms that have accrued enormous profits based on successful innovation are easy to find, but so are firms that have perished after having been successful for a while. In the light of such observations, *the lottery* looks like a valid metaphor expressing what innovation is like for individual business firm: Investing in innovation is very different from investing in an already established production system for which added revenues from system expansion can be calculated with some certainty. Innovation, like buying tickets in a lottery, is an uncertain endeavour whose final outcome can never be predicted with certainty, and whose economic results cannot be calculated. Furthermore, even though winners in innovation can make fortunes just like lottery winners, the number of winners is, as mentioned, surprisingly low. Finally, in spite of the fact that most of those buying lottery tickets lose, the lottery owner consistently profits. The reason is a curious mismatch between rather evenly distributed, optimistic expectations and the highly skewed rewards (McCaffrey 1994). In the case of innovation, society is in the fortunate position of being the *lottery owner*. As the annals of economic history demonstrate, in spite of the misfortune of most of the individual entrepreneurs and firms embarking on innovation, innovation pays off in the long term for industries and national economies.

Employing arguments on the micro-level that are relevant only at the macro-level is a well-known logical fallacy within the social sciences. However, no mistake should be made confusing arguments for the desirability of innovation in general and in the long term with arguments for innovation on the level of individuals and firms. Schumpeter's major contribution in his theory of economic development was to make it possible to understand how fundamentally irrational behaviour (in the economic sense) was underpinning the overall dynamism of the capitalist economy (Schumpeter 1983, 2006). In his early theory, he argued that it was the role of individuals, specifically men with peculiar personalities, to uphold the vital entrepreneurial function of the modern economy. He realized that whereas the economically rational thing for the individual to do is to abstain from staking their future on lotteries and on innovation, the well-being of all in the long term still depends on those few who disregard the normal calculations of probability and profit. What is irrational on the level of the individual is economically rational on the level of the overall system and over time.[1]

To reiterate: There is no immediate correspondence between the growth of the economy as a whole or of an industry and the economic development of the single firm. Society at large profits from entrepreneurs who – as has been demonstrated in research – systematically overrate their own chances of success in innovation (e.g. Cooper, Woo and Dunkelberg 1988). But no one can guarantee positive returns on investments in innovation. Often, such expense will render no economic value in return. Hence innovation investments can be a liability rather than a guarantee for survival in troubled times. On this background, it appears rather absurd that construction firms are so often lambasted for deciding to keep their expenditure on innovation at a low level. To mention but one example, the Egan report in Great Britain listed a number of symptoms and issues that it was claimed had to be addressed in order to improve the performance of firms in the sector. The sector as a whole was said to suffer from an anti-innovation culture that was in urgent need of change. According to the report, individuals, groups and firms would need to develop a stronger interest in learning, in developing new skills and in embracing novel technologies rather than resisting change (Egan 1998; Akintoye et al. 2012, pp. 6–7).

[1] It is interesting to note, albeit outside the scope of the argument in the present chapter, that Schumpeter creatively combined the idea of a micro-macro bridging mechanism such as Adam Smith's *Invisible Hand* with a Darwinian notion of survival of the fittest. The essence of his theory is the complex working of the entrepreneurial function that serves to bridge micro phenomena with the dynamic macro realities of capitalist economies.

In contrast, the argument in this chapter is that it can make really good economic sense to avoid speculative investments in innovation and to choose instead to use scarce resources in ways that are more certain to render additional incomes or reduce costs. Many construction firms struggle with projects and project deliveries, and making a profit often has to be a rather urgent priority (Foster 1969; Williams 2005). Hence, when resisting making significant investments in innovation, construction firms can be seen as rational and among the more sensible firms in the overall population of firms in the economy.

The fact remains, of course, that seen from a sectorial and societal point of view and seeing business in a longer time frame, low innovation expenditures do represent lost opportunities and reduced growth. What is rational in the short term and on the level of the single decision-making firm is not equally rational on the aggregate level and over time. Low investment in innovation in construction is a problem, even if it is understood as the outcome of rational individual choice. In this sense, government-sponsored experts and others concerned with the long run and future of industry and society may well be right in arguing for the need for more innovation. But believing that the culprits are firm-level irrationality and a traditionalist, anti-innovation culture is quite obviously misguided.

When doing research on innovation behaviour in construction, a reasonable assumption that is in line with good sociological research traditions is that firms and individuals more often than not are rational and tend to know what is good for them. If there is less interest in innovation in the construction sector than in other sectors, one should look for real and tangible reasons for this. Within an action and choice-oriented framework for analysis, such reasons can be discussed in terms of economic incentives, but can also be seen as related to informal non-economic factors, value orientations, social relationships, norms, formal laws and regulations and so on. Resisting here the temptation to enter into the heartland of theoretical sociology, let it suffice to point out that the tangible factors impacting on innovation behaviour certainly can be both economic and non-economic, but that these two kinds of factors are likely to blend together in specific cases.

Referring once more to the simple lottery metaphor, it would seem that positive *economic* incentives for innovation in construction might be smaller or less likely than in other sectors of industry. Motivations for innovation of *non-economic nature* must be seen in a different, non-economic perspective. It should be noted that in his seminal work on economic development, Schumpeter (2006) argued that innovation is something fundamentally different from rent-seeking behaviour. He insisted that innovation should not be seen as a purely economic phenomenon, even though innovation is often highly relevant economically and even though it is the economic repercussions that may be essential for the dynamism of capitalism. Reasons for trying to realize innovation, Schumpeter thought, had to be related to personal ambition, to the desires of individuals to put their mark on their world and so on. His discussion of such motivations has a somewhat dated appearance today, but as will be pointed out later, non-economic motivations for innovation are rarely hard to find. Arguably, it is only in a world in which economic and technical-rational thinking has come to dominate the *zeitgeist* and our life-worlds that it can be considered necessary to point out the otherwise obvious and plain fact that human beings have deep motivations for creating novelty and that these extend far beyond the mere craving for economic success. Tracy Kidder's (1981) book on the art and practice of making complex digital computers may be taken as a timely reminder of this simple fact. A close-up, ethnographic account of the process of innovation in an aspiring and fast-growing computer firm on the US east coast in the late 1970s shows unequivocally that even in the context of US high-tech business, the act of innovating cannot meaningfully be reduced to a quest for profit.

The lead focus for the remainder of this chapter, then, is *what factors influence firms in construction to act more economically rational and to be less willing to stake their future on innovation.* From an industry-level and societal point of view, as a follow-up, it would obviously be interesting to consider also what can be done to make firms in construction more interested in betting on innovation, and, hence, to act more like firms in innovation intensive industries. But this is a complicated question to answer, and only a few provisional remarks can be made in the conclusion of the chapter.

A Schumpeterian Definition of Construction Innovation

Innovation in the built environment is different from innovation in the mass production of goods, which was the key focus of industrial development at Schumpeter's time. However, the product and process innovation and the economies of scale typical for factory volume production have continued to influence innovation policy and innovation research until today (Drejer 2004). This is one reason why conventional approaches to mapping construction innovation in industrial statistics have serious weaknesses, and why the general understanding of innovation in construction continues to be weak (Gann and Salter 2000; Winch 2006). In spite of this, as Drejer (2004) points out, the fundamental insights needed to conceptualize innovation in a simple and coherent way across diverse kinds of industries and sectors are available in Schumpeter's work. In his theory, he considered the economy in the same way as the classical economists before him as a system of production and exchange in which human work is essential to create and exchange all things that serve to satisfy human needs. Goods and services are brought forth as combinations of resources. The economic system will tend towards a state of equilibrium where flows of materials and money are balanced and can be sustained. In the absence of external shocks, production activities take the form of repetitive operations and cycles. Competition entails pressure for efficiency, and this efficiency is realized through more effective division of labour, learning and gradual improvement and perfection of routines.

It is only at this point that Schumpeter makes his departure from the mainstream of classical economic theorizing. Innovation is introduced as interruptions and disturbances in the otherwise balanced system of economic production. An innovation is a novel combination representing a break with the past. The novel combination is usually not profitable at the outset, but can become highly profitable over time if it is successfully introduced and assimilated in the gradually transforming economic system. The fate of any new combination is uncertain, however, and the motivation for innovating cannot be based on rational and exact calculation of outcomes. Effects are to some extent unknown, and the fundamental motivation for innovation, according to Schumpeter, is not found within the realm of economics. Rather, the drivers of innovation are particular human beings – Schumpeter calls them *entrepreneurs* – who are (as Kidder also shows us in the book *The Soul of a New Machine*, mentioned earlier) passionate about their creation, and irrational in their uncompromising commitment to realizing their novelty.

As novel combinations, innovations are normally made from resources that were already exploited in the established system of production. Hence, innovation not only creates disturbances in the flows of this system but also tends to impact people being active in the established system. These people have competencies that have evolved and been perfected within the system. For this reason, capitalist dynamics are not simply marked by creativity and growth but also by disruption and destruction. Irrespective of this, innovation means change in the efforts people make to create things that satisfy needs, and it makes sense to define innovation as humanly intended and enacted changes in the routinized and institutionalized ways of value creation. Here, *value* refers not to profit, but to the generic utility of what is created – that it potentially, and directly or indirectly by entering into other combinations – serves to satisfy human needs.

Innovation in Construction

Winch (1998), Slaughter (1998, 2000), Gann and Salter (2000) and others have pointed out that being producers of complex systems, innovation is a *higher hanging fruit* for firms in construction than in several other domains of industrial production. When the argument is framed in the Schumpeterian perspective, it becomes obvious that production in one-off construction projects in itself has a lot in common with innovation: Producing value here is ultimately to create a concrete object (or sets of objects) that can serve to satisfy needs, which by necessity involves assembling many different elements into a new – and certainly in some ways also unique – combination.

Modern construction is a project-based, systems-producing enterprise depending on large and heterogeneous sets of project stakeholders. Built objects are as such complex and dynamic systems, produced by way of complex projects.[2] As pointed out above, production in routine-based service

[2] In the present chapter, complexity is defined as a property of systems. As argued by Luhmann (1984), *systems* are sets of elements that are functionally related. But only some elements are related directly. Other elements are linked only indirectly via other elements. Complexity arises because links provide the opportunity for feedback, and because each element has a limited capacity for entertaining relationships to other elements. Full integration is impossible, because each element can be directly linked to only a small share of the total number of elements in the system. Lacking complete integration, and with dependencies and feedback loops that are prone to transform over time, systems have emergent properties. Acting in such complex systems is always subject to uncertainty and risk.

provision and industrial mass production is perfected over time amongst others through task specialization, repetition and learning. In these cases, complexity (lack of integration, opaque functional dependencies, non-linear development and unpredictability) is reduced and transformed in ways that make it more manageable *in the production phase*. In concrete terms, production systems and organizations are established, stabilized and perfected over extended gestation periods (Hounshell 1984) so that volume production of a long series of identical and nearly identical products[3] can take place with only minor disturbances and variations in quality. Good examples of this are found in the car industry and in the semiconductor industry in which only the volume production of specific products can generate profits and create conditions for continuing research intensive innovation that can sustain the business in the long term.

What goes on in the production of the built environment is more comparable to the developments taking place before actual mass production commences, rather than to the serialized volume production itself. For this reason, construction is not well positioned to realize significant economies of scale. Complexity has to be tackled throughout the construction project: in design and engineering as well as in the assembly of materials, components and advanced technical systems. Lacking the option of trial runs and production system optimization in the ways of mass production, other strategies to deal with complexity must be used. Modularization, standardized detail designs and building product specifications, as well as proven routines institutionalised by way of informal norms and formal rules, are key resources in the efforts to make complexity manageable.[4]

The temporary nature of the construction production organization (encompassing both design and building), the emergent and non-linear properties of the development process and the floating nature of commitment and involvement of different contributors and stakeholders all resemble closely what Van de Ven and others have shown goes on in innovation processes (Van de Ven, Angle and Scott Poole 1989; Van de Ven et al. 1999). However, even though construction as a complex design and production process has some intriguing similarities with innovation, and even though construction in a very concrete sense is about making novel combinations, this should not lead to confound construction with innovation, or to erroneously conclude that construction necessarily is an innovative business. The key criterion for distinguishing innovation from other human activities is, as was pointed out above, essentially to what extent the activities concern sticky transformations of established approaches to value creation. Construction projects encompass efforts to establish a temporary production organization, but this approach to production of built objects is in itself stable, and changing it is not the target in most construction projects. In general, then, although construction projects may look like innovation, in reality they are not.

[3] Modern information technology and automation make possible the production of alternate configurations in a way that was impossible in the early days of mass production.

[4] A similar argument can be applied to other industries, such as the software industry and to more tangible engineering projects of many kinds.

Construction Innovation and Complexity

Some construction projects, such as the one described by Kreiner in chapter 3 in this volume, still aspire to be innovative. If innovation is to be realized, some change in the approach to producing built objects has to be realized, and has to stick and become part of future building activities and methods. As Whyte and Sexton point out, the heterogeneity of stakeholders and their differing motivations pose considerable challenges to those who wish to establish the level of trust and collaboration that is needed to innovate effectively (Whyte and Sexton 2011, pp. 477–78). This is not simply an issue regarding attitudes or communicative skills. Many different types of interdependent production are taking place in a construction project, but the interdependencies are not always obvious, nor are their effects simple to assess. The situation facing innovation oriented stakeholders is that complexity exacerbates the challenges related to determining what the key dependencies are, and finding ways to deal with them.

Dubois and Gadde (2002) have made the point that the couplings between firms in the construction sector are generally loose. Loose coupling can be seen both as a reason for complexity (lacking integration) and as a consequence of complexity: Looseness in itself represents an intended buffering, reducing the risk of externally induced shocks in a firm, or a project. According to Dubois and Gadde, this buffering is the source of considerable flexibility in the system, and it is therefore very useful. This is easily seen in the context of subcontracting and the use of temporary workers, which gives the project owner a very important ability to scale activities and mobilize specific competence in a timely manner, depending on project needs. At the same time, however, the condition of loose coupling reduces the efficacy of learning processes in the sector (Dubois and Gadde, pp. 628–29). This is seen amongst others in safety work, in which temporary work and many layers of subcontractors pose a very significant challenge. For the same reason, loose coupling also impacts the diffusion of innovation, and makes it harder to establish the integration and trust between stakeholders that Whyte and Sexton (2011) have pointed out are necessary to develop an innovation.

Construction Innovation and Asymmetric Information

Complex operations in many areas of activity depend on practitioners making decisions and creating solutions by which multiple concurrent needs and conflicting goals are balanced. Critical business decisions are made drawing on the knowledge and skills of those involved, much of which is tacit (Polanyi 1962; Wenger 1999). Formal calculations and technical-rational reasoning do play a role, but ultimately people make many critical business choices and decisions based on their own *gut feeling* and on the outcomes of negotiations between stakeholders (Schön 1982). It has been argued by several authors (e. g. Giddens 1991; Tsoukas 2003) that realizing the full potential of a human being depends on the individual's ability to *let go* of controlling particular aspects of a performance. To skilfully master a multidimensional and interrelated set of tasks, it is necessary, in a particular sense, to *stop thinking* about what is being done. This, of course, is true only when performers have rehearsed a great deal and are knowledgeable and skilful performers of the tasks. Such performers possess tacit knowledge, and, to paraphrase Polanyi, *know much more about what they are doing than they can easily express in words* (Polanyi 1962).

This general perspective also can be applied to practices in construction. Professionals, craftsmen and many of the other people who take active part in design and production are skilled performers. That a lot of what they know is tacit does not necessarily mean that it is unspeakable in a fundamental, epistemological sense (Tsoukas 2003). It simply means that they as stakeholders in the construction process know much more about what is being created by themselves and their colleagues than they care to formulate in words. As can be seen by observing construction project communication, some knowledge is shared, but in general information is very unevenly distributed between people (Emmitt and Gorse 2003, 2007; Dainty, Moore and Murray 2006).

It follows from this that *asymmetric information* is pervasive in construction, and this condition is so intimately bound to the fundamental properties of construction design and production that there is no easy way to do away with it. Even if we disregard the impracticability and high costs of close-up monitoring of operations on site, performance assessment will be really difficult because the reasons behind specific actions often can be fully known only by the workers themselves. With decision-making situations being complex and so much critical business knowledge being tacit, no single person will be in a position to base decisions on complete information (Winch 2010).

In his seminal article on *markets for lemons,* Akerlof (1970) presented a pioneering analysis of the consequences of imperfect information in markets. Pointing out how information on the state of a used car is asymmetrically distributed between a buyer and a seller, he showed in this article how the skewed distribution has detrimental effects, first on the market itself, but then also on the products being traded in the market. Akerlof was interested in why markets for used cars structurally get into a vicious circle when the prices of cars and the quality of old cars spiral downwards, leading to the said *market for lemons*, and to markets contracting and sometimes drying up completely.

The point here is that the very same logic that Akerlof applied to the market for used cars can be applied to the market for building services and for buildings. Under conditions of severe asymmetric information, prices for services rendered in building will not reflect the quality of the services provided. Rather, prices will be discounted, reflecting buyers' assessment of potential value and the risk they face that what is offered is of substandard quality. This effect also has been empirically verified subsequently, for instance, in an analysis of the effect of property condition disclosure laws on housing prices (Nanda and Ross 2009).

What is pertinent to note here is the following: It follows from the condition of asymmetric information and the lemon market logic that it generally is *economically irrational* for craftsmen and other service providers to provide superior quality in construction, and for builders to deliver a more than average quality building. This follows from the general fact that pricing will fail to match the efforts and costs of providing higher quality. Extending this logic, the lemon market logic represents an *economic disincentive* also for innovation in construction. When the merit of higher quality is not seen or understood, or for other reasons disregarded by buyers, investment in quality improving innovation simply does not pay. In this context, relevant buyers are not only the end users. Also, professional builders, craftsmen and others will be affected by asymmetric information in a similar way (but perhaps in a less serious way, because they may be more knowledgeable about what is going on than the average end user).

The condition of asymmetric information, then, undermines the link between performance and price along the value chain, and hence, reduces economic incentives for quality improvement. But can this argument be extended to the discussion about economic incentives for *innovation in construction in general*? As pointed out earlier in this chapter, the basic economic incentive for innovation is the chance of earning big money in the fortunate case that innovation actually succeeds. It is not clear that all kinds of innovation will be disincentivised by an underperforming market in which the link between performance and price is weak. If, for instance, innovation would entail a stronger position or even monopoly in a market, then innovation would be economically interesting regardless of asymmetric information issues. However, in all cases when innovation is oriented towards inconspicuous quality improvement, such as when replacing standard gypsum boards with water-resistant boards in wet rooms (Orstavik 2014), there will be little economic incentive for innovation.

Construction Innovation and Multi-Parametric Optimization

Much of the work going on in construction can be conceived of as concurrent systems building. Complexity is a property of systems, and production of the built environment encompasses a multitude of systems, each of which has a degree of complexity, and that also are related to each other in complex ways. The basic physical structure of a built object consists of many related elements forming a system with some advanced properties, for example, physical flexibility and robustness. A number of specialized subsystems are created and related to this basic structure and to each other. For example, technical contractors develop technical systems for air circulation and climate control, lighting, electricity supply, water circulation, elevators and so on. Other specialized firms may be employed to deliver façade systems, fire protection systems, and so on, within the larger, composite system of the built object. Each is a system in its own right and with its own particular logic, but several systems have to be connected functionally. That is to say, several subsystems must be made to interoperate. This interoperability – what Luhmann in his systems theory (1984) called 'interpenetration' – is achieved by technical means. For example, the electrical system and the water system, which are closed off from each other in order to function, are made to influence each other at some points. These are nodes where internal events in one system are used as input in the other system. (For example, the flow of water in a faucet can be steered by electrical signals from a photo cell.)

Both the built object and the building project as such can be conceived of as complex systems. Each is created by stakeholders in the course of a project, and operations in a construction project while targeted primarily at one system (say, plumbing) must not come in conflict with other systems. Actions and decisions related to operations both in design and production will first and foremost have to be justified as adequate with respect to the system to which they belong. However, assessment of the adequacy of what is created cannot be done in complete ignorance of the other systems. Division of labour and specialization serve to *reduce* and *structure* complexity. In practice, this means that work chores for many stakeholders are simplified, because they are able to concentrate attention on the economy and functionality of *their* own system. (It is, for example, largely sufficient for the plumber to make sense of the system of plumbing and make sure dependencies between elements of this system are taken care of properly without using too much time to sort out unforeseen problems.) However, making operations economical and adequate within the whole project cannot be ignored completely, and most obviously, not by those designated with some level of managerial responsibility, for example the gang leaders, foremen and project leaders.

To different degrees, then, concurrent system building is a challenge for all stakeholders in the construction project. Even simple operations can have unforeseen consequences. (For example, the electrician cannot put cables where the plumbers have placed their pipes, and if pipe positions are moved because of a specific solution devised by carpenters in response to a particular requirement made by another stakeholder, such as the buyer of the flat.) Thus, those involved are faced with the need to balance many different needs at the same time. The outcome of specific operations might easily be optimized with respect to a single issue (the wall can easily be put where the buyer of the flat wants it so that she has room for her large bed), but in building, only exceptionally if at all, can the outcome of an operation be optimal in every respect that is considered significant by all interested parties. (Is it worth creating space for the large bed, considering the extra work that has to be done by the carpenters, electricians and plumbers?) A balance has to be struck, and given that resources are limited, it is to be expected that solutions chosen are deemed as imperfect by one or more, or even all, stakeholders.

The essential point to notice here is that the outcome of operations may be suboptimal in most respects, and still they can be considered optimal from a systems perspective. Economists use the term *Pareto optimality* to highlight a specific criterion for systems optimization. The simple definition of a Pareto optimal state of affairs is that no single improvement can be made to any element in a system that would create a net gain for the system as a whole. In other words, when all possible improvements in a system create side effects that incur costs that are higher than the gains achieved, the system is Pareto optimal.

Considering the built object a system of systems, Pareto optimality is the abstract ideal for what can be achieved for the finished edifice, and for the operation of the building project. Pareto optimality is, however, an abstraction that cannot be fully operationalized in situations with high complexity. In practice, it is not possible assess a built object, or a building project, as a system in a way that would make it possible to decide when Pareto optimality is reached. Seeing that optimization of a complex system also has a temporal dimension, this becomes even more obvious: There can be no way to judge in practice what impact current actions have on the possibility to achieve Pareto optimality at a later stage in a construction project.

In spite of this, it may still be wise to use the idea of Pareto optimality as a guide to action and to decision making (a so-called heuristic rule). This would mean that stakeholders and contributors have to be somewhat modest with respect to their own interests and efforts in the projects. A Pareto optimal outcome would not depend on reaching optimal outcomes on any single relevant measure, but the opposite: The best outcome can be realized only if everyone is willing to negotiate actively with a commitment to contributing to a balancing of all relevant concerns in the project.

This approach to multi-parametric optimization can be observed in practice in many construction projects. A wise project manager knows that it is pointless to optimize single aspects of what is produced, because this would add little to, and possibly detract much more from, to the total result. Given unavoidable constraints on resources, perfection is something that it makes little sense to demand or to deliver for any single stakeholder in a project, and for any single aspect of a project. That which is *good enough* is actually better for all, because the system as a whole benefits from less than optimal solutions in the various subsystems that make up the totality.

What room then, is there for innovation in a project in which the ideal must be multi-parametric optimization of a complex system? It would seem that incentives for innovation are weak unless the innovation has properties that make it possible to improve performance of the entire system – be it the project as such, or the built object. (Low-cost temporary covering systems that make dry building possible in wet climate, and cost-reducing new technologies applied to a subsystem such as plumbing, could be an examples of such innovations.) In many other cases, multi-parametric optimization will function as a deterrent for cost-increasing and quality-improving innovation. Ongoing negotiations with multiple stakeholders will always limit what single stakeholders can achieve within their particular domains. A quality or performance improvement cannot be assessed simply on its own terms under the assumption *everything else constant*. Any innovation that promises to consume additional resources will have to be assessed on its merit relative to what is lost in other parts of the project. This, it seems, represents a significant impediment for the diffusion of innovation in construction, and would lead to the kind of needs for promoting innovation that are suggested in chapter 11 by Rose and Manley in this volume, in which stakeholders have to be actively persuaded that suggested innovations actually deliver net benefits to the project as a whole and to the totality of what is being created in the project.

Conclusion

The discussion of incentives for innovation in construction in this chapter has shown that high complexity negatively influences the extent to which firms and individuals can expect to succeed and in experiencing significant economic gains from an innovation success. *Complexity creates uncertainty, and makes stakeholders more prone to stick with established methods and solutions in their work than they would have been if the level of complexity were lower*. The mode of production in construction is quite specific (but far from singular) in its mode of managing complexity. Practice-based learning and tacit knowledge are essential in creating conditions of asymmetric information. This leads to a price-performance disconnect, creating economic disincentives for quality-improving innovations. It has been suggested that this disincentive may be less strong for some innovations, for example, innovations that lead to a firm's increased market power. It has, furthermore, been pointed out that a combination of complexity and loose coupling of stakeholders may create vicious circles, that is, a self-reinforcing mechanism in which both complexity and loose coupling is sustained. The argument has been made that this leads to unfavourable conditions for learning and the diffusion of innovation. Finally, the notion of multi-parametric optimization has been employed to show that the nature of construction production as concurrent complex systems building also is a factor that leads to disincentives for cost-increasing, quality-improving innovations. It would seem that this mechanism creates a bias for innovations creating systems' level improvements. These innovations can be designed to improve both the construction project, and the whole of the object that is being built.

The common thread running through the entire discussion in this chapter is information. Insufficient and asymmetric information is the single issue that reduces economic incentives for innovation on the design and production of the built environment. The opacity of interactions in the process of design and production influences firms via several different mechanisms to act more economically rational and to be less willing to stake their future on innovation. It is really difficult to win big by making and diffusing specific innovations, because even limited innovations may affect the system in ways that are difficult to map and to comprehend.

Empirical research is needed to develop the theme of this chapter more fully, and to corroborate the conclusions. There is a rather obvious limitation in the present analysis, because it builds rather single-mindedly on the Schumpeterian idea that innovation is always risky and outcomes unpredictable. No doubt, negotiated improvements in current business processes in projects and firms are occurring and may represent significant innovation. As pointed out in chapter 13 in this volume, innovation is also taking place in the manufacture of building materials, tools and equipment that find their way into both the design and the production of the built environment. Some of these are clearly systemic, such as building information modelling, while others are not.

Recent contributions to innovation research, which may prove fertile for the continued research on innovation in construction, explore whether novel approaches to organizing innovation could have a potential to deal more effectively with uncertainty. These contributions tend to approach the innovation phenomenon from more systemic position than before. For instance, by focusing on service systems innovation (Den Hertog, Van der Aa and de Jong 2010), this research is trying to substantiate Schumpeter's late insight that the entrepreneurial function can become internalized in the capitalist economy, making the single and fundamentally irrational single entrepreneur entirely a personality of the past (Schumpeter 1976; Osterhammel 1987).

A final point worth repeating is that even though the focus in this chapter has been on economic incentives, the primary motivation for innovation does not need to be economic. It can be related to the needs for sustainability, for safety in the workplace or for a host of other important issues. The creation of novelty reflects basic human inclinations, and innovation contributes in a fundamental way to shaping the world far beyond the fact that it creates high profits in successful firms over limited periods of time. This broader significance of innovation in construction is certainly also deserving of more attention in research.

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3

Built-in Innovation and the Ambiguity of Designing Accessibility

Kristian Kreiner

Beautiful things only offer themselves to those who offer themselves to beautiful things.

(Hennion 2013)

Introduction: Making Innovation Accessible

In this chapter, I aim to learn about innovation in construction from a project that was designed to develop the world's most accessible office building. My focus is on the design phase, which included an invited 'design and build' competition between three consortia of contractors, engineering consultants and architects. Words are performative, but within limits. Being conceived of as an innovative project does not imply that a project will also have an innovative effect – in whichever way we make sense of innovation. Designing even the most accessible office building might easily imply doing more of the same, with more or less the 'usual' results. Were this to be the case, it would be almost too easy for the client to rhetorically declare victory and success, because nobody knows the meaning and grading of *accessibility*. This ambiguity of the primary term 'accessibility' and its relationship to the office functions of the building is a fundamental premise of the design studied here and for my reflections below, which aim to locate and understand the phenomenon of innovation.

The concept of innovation is a concept that is commonly used, yet is hard to define meaningfully. We effortlessly think *with* the concept and seldom think *about* it (Ryle 1962). When we are asked to define it, it slips away by being conceived in terms of its sources (Hippel 1988), its effects (O'Hare

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1988, Marceau 2008), or its organizing and management (Tushman and Nadler 1986; Tushman and O'Reilly 1996). Schumpeter (see the introduction to this volume) comes closer to thinking *about* innovation in suggesting that it entails a qualitative reconfiguration of already existing elements. The entrepreneurial function was one of recombining things, with the further presumption that the resulting invention would compete for primacy with the existing combinations and alternative inventions in the market.

It is such a Schumpeterian notion of innovation that frames my quest. I will be searching for new things being done and for things being done in new ways. We have to realize, however, that designing and constructing an office building necessarily engage an overwhelming number of routines and standard procedures that will easily dominate any desire for change and may also easily hide change. The institutional framework of competitions, projects and contracting puts limits on the recombinability of the various elements (Kreiner 2013). We also have to realize that any project is unique and that changes may simply reflect local adaptations to the unique circumstances of the project rather than a more general innovation. With all such ambiguity as its backdrop, the research question guiding this chapter is: *Where is the recombination taking place, and with what implications for the elements being recombined?* If this question can be answered, I will claim to have located innovation and to have created new input into a continued reflection about the concept of innovation, in theory as well as in practice.

Conventional Connotations of Innovation

In dictionary terms, *innovation* means to 'make changes in something established' (http://oxforddictionaries.com; accessed June 29, 2013). Thus, change is a central characteristic of innovation, but change is also relative, presupposing some knowledge of what it is that has changed.

In fact, change in itself hardly counts as innovation, because that concept seems to imply some kind of *desirable* change. That is, there is a presumption that the change is for the better, that it represents an improvement, a step in the right direction, that it has value. Marceau (2008) conceives of innovation as the (economic) value of novelty. Of course, value is also relative. The literature contains different answers to the *cui bono* question (Blau and Scott 1962). Some point to the value for the customer (O'Hare 1988), whereas others would (implicitly or explicitly) claim that value for stakeholders or stockholders is the ultimate measure.

A third connotation would be that innovation is a result of purposive human action, that it is not a random occurrence, not a serendipitous change that turns out to be valuable, not a gradual evolution, but rather that it is brought about by intent, choice, strategy and guided effort. It is an event, an episode, a project.

The fourth connotation reflects the fact that purposive human action builds on knowledge and information. In the post-capitalist society, says Drucker (1993) 'the only – at least the main – producers of wealth are information and knowledge' (p. 167). Innovation is the epitome of modern society, and therefore the role of knowledge is central. A classic formulation is the following:

> *Innovation is the successful exploitation of new ideas*. (Innovation Unit, UK Department of Trade and Industry 2004, quoted from Tidd and Bessant 2013)

It is probably safe to assume that innovation starts with new ideas that are subsequently transformed into knowledge that can be packaged into new products (Drucker 1993, Kreiner and Tryggestad 2002) – products that can be sold on a market (Tidd and Bessant 2013). In this sense, innovation is founded on new ideas and knowledge.

That the 'successful exploitation of new ideas' is an organized and systematically managed process is the fifth and final connotation of innovation. It comes about in planned, orchestrated and designed procedures. Tidd and Bessant (2013) represent this understanding well when they suggest that innovation entails *searching* for new ideas, *selecting* the good ones, *implementing* them and *capturing the value* in the market. It implies achieving something new by rationally selected means and procedures.

Innovation is change that is valuable to somebody, that is the result of purposive human action, that exploits new ideas and knowledge, and that is achieved through a rational, managed procedure. Even if they conflate outcome, process and purpose, such conventional connotations are useful because they allow us to talk about reality in an informed manner. For the current purpose, however, they should be used critically – or *innovatively* – if we want to learn new things about innovation from the empirical case. The point is not to reconfirm conventions by interpreting the case in terms of what we already know and agree upon. The point is rather to challenge (and potentially improve) such a priori knowledge and understanding with the realities discovered in studying the design of the world's most accessible office building.

The Plan of the Chapter

After a brief discussion of the methodology of the case study, I will give a detailed account of the process of developing the world's most accessible office building. It is an exposition of the challenges that the participants faced and their explanations after having completed the task.

In the course of this discussion, I challenge the common connotations of innovation on two main counts. First, I show that the potential value of the change is not constituted in the design of better solutions to the users' needs and problems. The fact that the nature of the problem of accessibility prevents solutions to be found sends me searching for the ways in which things could be claimed to have improved. Second, I show that new ideas and knowledge about accessibility are not accumulating in the design process. What is gained is a new 'taste' for the dilemmas of design, knowledge in the sense of a new awareness of the character of the problem and a change in fundamental strategy.

In the conclusion, I pinpoint the discovered recombinations of elements that constitute the innovation of designing the world's most accessible office building. I also return to the above conventional connotations to suggest other more suitable connotations for practice.

Methodology

Being part of a larger program called Memorable Projects in Construction, this study was initiated to document an unconventional practice in relation to design and build competitions in the construction sector. In this case, the unconventional practice was a training course in design for accessibility that was an entry requirement for the architects, engineers and contractors participating in the competition. We did not observe the training course, but participants who pointed us to this project all referred to the course as a significant, eye-opening experience. Thus, we approached the study with the strong expectation that something extraordinary had been going on, and we wanted to understand what made this project so extraordinary in the minds of its participants. Only subsequently did it become a concern how such an extraordinary procedure also led to innovation.

Our methodology can be described in four separate steps: the desk research, the interviews, the analysis and the validation of our results.

The Desk Research

We collected all publicly available information about the project, the participants, the stakeholders, and so forth. The high visibility of the project in the press made the task easier.

The Interviews

We conducted semi-structured interviews with central actors in the design competition. This included representatives of the client, the client consultant and the three firms on the winning team: the architect, the civil engineer and the contractor. Most interviews lasted approximately two hours and were tape-recorded and subsequently transcribed in full. They were structured to ensure that we could document the episodic procedures and processes by triangulating several more or less independent accounts. The interviews were open in the sense that we were interested in learning the participants' individual experiences and reactions to the competition.

The Analysis

The data collection enabled us to give a full account of the project as a historical episode. Our own analytical efforts were directed at understanding both the intended and the revealed rationale of the planning of the competition and the subsequent design and construction task. It focused on the enabling of dynamic learning and experimentation, for example, by motivating participants, combating routines and existing networks and calming the anxieties of external stakeholders (Kreiner and Haukeland 2012).

Validation

On various occasions, and in various forms, our documentation of the project history and our analytic interpretations were shared with the participants and the industry at large. This validation process added new insights, but in such a manner that the trustworthiness of our account and our interpretations was reaffirmed.

The Case: The World's Most Accessible Office Building

Having the Queen of Denmark inaugurating an office building is a signal that this is not an ordinary building and/or client organization. Perhaps this building was worthy of the Queen's time, because it promised to be the world's most accessible office building. Perhaps it was because the client was the Disabled Peoples Organisations Denmark (DPOD – http://www.handicap.dk/english) and its 32 member organizations, each representing the interests of a specific type of disabled individual. In both respects, the project symbolized a worthy cause, a fact also acknowledged by a number of private foundations readily funding the four-story, 12,600 square meter office building at a cost of 180 million DKK, the equivalent of EUR 24 million.

This worthy cause also had innovation at its core. It was rhetorically framed in the name of the project, 'The world's most accessible office building', and was elaborated in the design strategy for the new building:

> *We want to construct the world's most accessible office building – with equal focus on modern office spaces and equal accessibility for everyone. Only by integrating solutions that could also work in other buildings can you really speak of a house that will spread its innovative solutions like ripples on water far out in the world. … Through new projects and using its own thought out solutions, this house will act as a generator for the disability cause and a universal design in the future.* (Quoted from the project's homepage: http://handicaporganisationerneshus.dk/in-english/design-strategy; accessed June 26, 2013)

The mundane task of providing shelter for the administrative staff of the DPOD and its member organizations was defined as a unique occasion for doing something more profound in terms of promoting the disability cause. The project was translated into a quest for innovation on an industry level. The vision was to use this project as a means to change building tradition and design practices not only in Denmark but across the world. To accomplish this, the project needed to create new knowledge about building accessibility and better solutions to a problem that has been too often put aside in modern architecture and society.

In the following, I will describe the many ways in which such innovative ambitions inspired and impacted the design and enactment of the 'design and build' competition that was organized for this project. A full account of the process can be found in Kreiner and Haukeland (2012), whereas a briefer summary can be found in Clegg and Kreiner (2013).

The Meaning of Accessibility

A slogan such as 'the world's most accessible office' building serves more to motivate than to inform. Nobody knew – or could know – what it actually meant or implied, but it signalled an ambition for figuring it out. Instead of treating accessibility as a formal requirement (e.g. a matter of compliance with the building code), singling it out as a primary focus of attention promised a new starting point for the design process.

In a literal sense, the client organization and the disabled users it represented had all they needed in terms of experiential knowledge about inaccessibility. They knew about the problems, and they knew better than anyone else the limits of the existing solutions. However, for reasons to become clearer later, they had vague ideas about any *good* solution to the problems of building accessibility.

In lieu of specifying solutions, the DPOD spelled out a vision for a future practice that such solutions should enable. This vision was included in the design strategy for the office building. It also represented an extensive reflection on the meaning of accessibility, emphasizing the following two characteristics:

- '*Equality. Overall the house must be equal for everyone*'. This vision creates an immediate dilemma: 32 different types of handicaps make a building inaccessible in as many different ways and providing accessibility for any one type of user may easily make the building less accessible to all other types of users. But the principle of equality was conceived in a more profound sense. Special provisions for disabled users would perhaps gain them access to the building, but potentially at the cost of a temporary social exclusion. Using a mechanical wheelchair ramp, for example, would put the user's disability on public display and force him or her to take a different route from travelling companions. Equality meant that the building would grant access without such social exclusion. 'On principle, we have decided to work with only one solution that can be employed by everyone.' The ideal was thus to design a building for *all* users, disabled and non-disabled alike. Accessibility should be an integral part of the design, not a special remedy added subsequently to assist a special user group. (All quotes are taken from the project's homepage, op. cit.)
- '*Universal design. … In general, we have prioritized low-tech solutions rather than high-tech solutions because they will become an integrated*

part of the architectural solution that won't be more expensive than other non-accessible solutions. We support and encourage thereby all users of the house to be self-helped.' To make accessibility a fundamental aspect of the building design rather than a subsequent add-on represents an ambition of saving the need for costly, architectonically superfluous, and socially demeaning special remedies and provisions for disabled users. One type of physical building layout may enable people to find their way *themselves* better than other types of layout. The self-helped user is the ultimate symbol of accessibility having become an integral part of the building design.

This ideal of designing an accessible office building represents a new way of approaching the problem. It suggests new criteria for evaluating the quality of specific design ideas and proposals. It instructs architects and everybody else involved to look for solutions in new places. But obviously it does not say much about what will be seen and found when looking for solutions there.

The Wicked Problems of Designing for Accessibility

According to informants from both the client organization and the participating consortia of architects, engineers and contractors, when looking for solutions, all they found were problems and challenges. Accessibility turned out to be a wicked problem (Rittel and Webber 1973). In fact, we can see intuitively that the problem is complex and difficult. Remember, for instance, that physical structures are by nature obstructions and that we design buildings to be *in*accessible in multiple ways, such as to unwanted intruders like rain and thieves. As mentioned above, however, the conventional remedies to this fundamental inaccessibility may in many ways add to its inaccessibility relative to a specific handicap, which will then require further, specialized remedies – remedies that may in turn help some but aggravate problems for others. For example, the physical obstacles we remove for the sake of wheelchair users may also remove the resources that blind people use as waypoints to orient themselves. Even if the DPOD tried to reduce the complexity of the design task by selecting seven disability groups ('wheelchair, gait/arm/hand, hearing, vision, development, reading and allergy – and we have supplemented these seven groups with severe obesity', quoted from the project's homepage, op. cit.), it is still unclear what a general solution would look like.

In the course of the 'design and build' competition, and subsequently during the construction of the building itself, a user panel offered assessments of the various proposals that the consortia presented. Generally speaking, the feedback was negative in the sense of pointing out more concerns and consequences of proposed solutions.

Two of the consortia had proposed a circular layout for the building, with a ramp going all the way up the building, i.e. a spiral in order to avoid any hindrances. Then, to see them receive the feedback! 'Oh,

> *ramps are so long; they are so exhausting; it is so hard to walk up; and for blind people a spiral, like a round atrium, is a never ending spiral: how should they know that they have reached the desired floor or hallway?' … [The consortia] sounded out their design concepts and [the ramps] disappeared in all proposals. They used the feedback constructively.* (Consultant – my translation)[1]

> *It was a great advantage that we had the opportunity to sound out our ideas. In fact, the first ingenious proposal we came up with did receive some praise, but was also shot down, among other things because it was round and for a person with a visual handicap that doesn't work! … Then we had learned that lesson.* (Contractor – my translation)

This process is characteristic of working with wicked problems (Rittel and Webber 1973). It is by proposing solutions that you discover new aspects and new dimensions of the problem. The problem for the designer is the fact that the process only stops because you run out of time, not because you finally find a solution. There is no solution to a wicked problem, only a more or less informed design that copes more or less successfully with the situation (Conklin and Weil 1998).

Recognising the Quality of Informed Design

At some point in time, choices had to be made if the building was going to be designed and constructed. These choices had to package the call for equal accessibility and universal design with an appreciation of the wickedness of the problem. The resulting design was not a solution or even a compromise, because that would indicate an imperfect solution, but a solution nonetheless. The choice was perhaps more akin to a 'speech act' that holds promises for the future, and which will be meaningful in an ongoing conversation of turn taking (Zimmerman and Boden 1991). It represented a discontinuity in the conversation, an end to the conversation with the client and the user panels and the beginning of a conversation with the competition jury. The choice was informed by the previous conversations, but these were necessarily represented in a very implicit manner. It takes a special gaze, competence and experience to decode the accessibility of a building when the design reflects informed understanding, and when the usual visual markers (like handicap toilets and special ramps) have disappeared. For these reasons, the performativity of the speech act was uncertain and unpredictable when the new conversation introduced uninitiated participants.

Surprisingly, among the uninitiated observers, we find the professional members of the competition jury, architects, engineers and representatives of the local municipality. They lacked the background for understanding accessibility in other terms than obtrusive remedies. They had no prior experience

[1] All interview quotes in this chapter have been edited to make them more readable, without changing the intended meaning.

or training that enabled them to perceive the issues more abstractly. Thus, it is no wonder the professional jury members were said to have expressed disappointment with the accessibility solutions in the entries. They opted instead to evaluate the various entries on traditional architectural merits. But the jury disagreed internally, because the client's strong representation was better prepared for recognising the equal accessibility and universal design in the various entries. In the end, the users' interests prevailed in selecting the most accessible office building over the more architecturally aesthetic alternatives. But this victory came at the expense of having made the accessibility of the building invisible and therefore inaccessible to most of its uninitiated critics.

The Eye-Opening Experience of Being Blindfolded

In the working on the design problem and in their interactions with the user panel, the participating consortia had developed an appreciation of the problem and its multiple dilemmas. They kept experimenting with new ideas and proposals much longer than a strict rationality would predict. If the design problem is a wicked one that will never allow for solutions, but only reaffirm fundamental dilemmas, why did the negative feedback not discourage the participants from continuing with their experiments? If this extra effort could not easily be recognised in the demonstrated quality of the design solution, the whole process might seem a little futile. To understand this apparent irrationality, we have to go back to an earlier point in the process and reflect on the formative moment in the lives of the participants. The formative moment came during the obligatory training course on design for accessibility that the prospective architects, engineers and contractors participated in prior to the design and build competition. To oblige seasoned professionals to take such a course is highly unconventional as well as somewhat controversial, because it seems to signal that the professionals lack the necessary qualifications for participating. But it also signalled the unconventional vision and ambition on the part of the client.

The training course was designed as an experiential learning adventure. The participants were blindfolded and asked to find their way around existing buildings; they were also confined to a wheelchair and asked to get into and around ordinary office buildings. The final assignment was the analysis of an architecturally renowned office building from an accessibility point of view. Based on their experiences as users with simulated disabilities, the participants were beginning to recognise new design problems and started producing ideas about the need to remedy the situation. However, they were selected for participating in the competition not on the basis of the quality of these ideas, but on their demonstrated ability and willingness to recognise the wickedness of the task and the inadequacy of their existing capabilities.

Whatever the specific content of the course, it is not hard to recognise the 'secret' or implicit learning plan: The concrete experiences should instil a user perspective in the minds of people who normally approached the accessibility issue from a design or construction perspective. This change in thinking had a great impact on the participants – even to the extent that some of them were visibly emotionally moved when recounting the event. In later accounts of the experience, they referred to a feeling of travelling along a 'steep learning curve'. They realized things about their previous domain of practice that they had never been aware of before. The sudden revelation of a different reality (i.e. the unexpected insight into concerns and complexities that had previously been hidden and ignored) had a profound impact on the motivation of these professionals. In many ways, they acted to learn more, to get a deeper appreciation of the complexities of the building accessibility issue to the point that ensuring an efficient completion of the task seemed secondary. This pattern of behaviour lasted well into the actual construction phase when the contractor continued to conduct experiments at his own expense (e.g. with new fire escape technologies).

Innovation Issues for Further Consideration

The design strategy presented the problem in terms that seemed to prevent good solutions and only allowed for informed compromises – even if general solutions were promised in the design rationale. However, there may be no way in which a building (a physical structure) can be accessible, only different and more or less discriminatory ways in which it can be inaccessible. Finding ways of designing the building so that all users can 'force' their way in and around (i.e. to make their individual project feasible or even facilitated) may be a better description of the design task than the rhetorical version of creating accessibility solutions. But to design such buildings requires a broader understanding of the interaction between individual users and the physical structure.

Discussion: In Search of the Innovation

It is time to return to our reflections on the concept of innovation as the backdrop of this specific case. Will it provide an opportunity for developing a better and more nuanced concept to think with about the many problems of organizing and managing construction?

In conventional terms, we would have no difficulty talking about this project as a case of innovation. Certainly, the people involved in the project have produced something new through a dedicated effort guided by a purpose of being useful and valuable to somebody else (both disabled users of the building and designers of future office buildings). We might easily catch ourselves talking about all the knowledge gained in the described process of trial-and-error learning as having been packaged into this design and future ones. But my aim was not to be able to talk about the case in conventional terms, but to learn new things about innovation as such. This is still the aim as I proceed to analyse two aspects of the project, namely the nature of the achievement and the role of knowledge in design.

User Value and Affording Designs

Conventionally, to claim something to be an innovation implies a value of novelty. To build the world's most accessible office building seemed destined to produce such value, but we would soon discover that we were confusing the purpose and the achievement of the effort (i.e. using 'innovation' as a synonym of 'trying to innovate'; Ryle 2000). The value to the users would depend on more than just the building, however it was designed. At the least, it would depend on the actual users and their actual use of the building. Thus, in fact we cannot know whether we are studying an innovation until the *value has been proven in the use of the building*. Because we cannot wait for that to be proven, we do as we normally do when we cannot know the things we need to know in order to act: We substitute theory for knowledge (Loasby 2000). Thus, the change that underlies innovation may be a change in the theory about how the physical structure of the office building is being used, more than a change in the physical structure itself. Such a change was already signalled in the design strategy when it was claimed that the building should 'support and encourage … all users of the house to be self-helped' (project's homepage, op.cit.).

Theorizing the use of physical environments is not the domain of innovation research, but it is central to environmental psychology. Gibson (1986) may help us illuminate the issues of such a theory. In his formulation:

> *The affordance of something does 'not change' as the need of the observer changes. The observer may or may not perceive or attend to the affordance, according to his needs, but the affordance, being invariant, is always there to be perceived. The affordance is not bestowed upon an object by a need of an observer and his act of perceiving it. The object offers what it does because it is what it is. To be sure, we define 'what it is' in terms of ecological physics instead of physical physics, and it therefore possesses meaning and value to begin with. But this is meaning and value of a new sort* (pp. 138–39).

The concept of affordance allows us to see the value of the building design in what it *offers* regardless of the degree to which such offers are received and accepted. The concept offers what it does because it is what it is – and partly what it is designed to be. But the affordance exists only in the relationship between specific types of users and the 'thing'. It may allow some people to do things they could otherwise not do; it may prevent other people from doing what they would want to do; and it may be a general backdrop to the lives of still other people. The ways in which ordinary office buildings are made accessible to disabled users make this point clear. The stairways that afford most users to climb the building leave wheelchair users stuck. A particular flower with a distinct bouquet will be just that to most users, but may be a landmark for the blind user when he or she has learned to locate the smell on a mental map of the building and may be a visual warning to users with allergies. To design a building with stairways and flowers will invariantly make it resourceful, but it will naturally be differently resourceful to the different users of the building – and in many cases, it will simply be redundant (i.e. providing resources not needed for carrying out some activity). Perhaps the ambitions for a universal design and equality can be understood as a search for types of affordances that do not discriminate between different users. When the needs of distinct groups of users must be met by specific means, the ambition is then to design means that can offer something to everybody. The carefully chosen colour shading of hallways and doors may allow the visually impaired user to distinguish the door from the wall, and may offer all others an aesthetic experience. Even the most innovative design of the building does not nullify the differences between the multiple user groups and their individual manners of relating to it. After all, users have different needs and different projects that bring them into contact with a building. What is new is the ambition not to reflect those differences in the building design. The design should allow all users to be self-helped and thereby to forget-rather than being reminded of – their disability in their confrontation with the building.

The challenge can be expressed in terms of the 'demand character' that things have (Koffka, quoted in Gibson 1986, p. 138). In his view, things tell us what to do with them. They have meaning before they are used as resources. But the conventional meaning – the stairway asking to be climbed – may be exactly the kind of demand that disabled users are unable to answer. To design equality into the building means to make demands that all can answer. A toilet that can be used by wheelchair users is still a toilet to the non-disabled provided that it is recognised as a toilet. Sometimes the demands of things are muted and may require special needs and qualifications to be recognised. Flowers are resources to some users and merely a non-demanding pleasure to most others. Furthermore, some carefully designed provisions may be perceived by nobody, and things not intended as resources for accessibility may develop such meaning over time.

We may imagine innovation to reflect the development of such a non-discriminatory language of things – to elaborate the vocabulary of a nonverbal language (e.g. a visual language [Fernande Saint-Martin, quoted in Pacey 1999, p. 83]). The design of accessibility is a way of communicating with prospective users through the physical structures and distributions of things. The messages are necessarily conventional because the projects that bring users into interaction with the building are unchanged and the required resources for accomplishing them are well known. But the vocabulary is supplemented and developed to provide more *honesty*. Gibson (1986) reminds us that when things say what they are, they may also lie. The fact is that the stairway lies to the wheelchair user, like a misplaced flower lies to a visually impaired user. Making buildings accessible could be translated to an issue of *honest* physical structures.

Let us not fool ourselves. Such honesty may be construed as an absence of solutions or a lack of sophistication. The professional jury's disappointment proves the case. The affordances and subtle messages of the building may in similar ways be wasted on future users, journalists, politicians, and so on. Specific uses that may become institutionalized will prevent the exploration of the bricolage of things and features that could be turned into resources.

In short, we cannot be sure of the fate of the world's most accessible office building. But we may have found a new way of theorizing its dispositions to afford equal and inclusive use by honest communication and fair demands.

Knowledge Packaging and Innovation

Conventionally, we think of innovation as relying on superior ideas and knowledge that become packaged into marketable products. We know how this position further relies on the idea that the use of the product is pre-established and that the users are thereby co-designed with the product (Kreiner and Tryggestad 2002). The interface between the user and the product is already designed as invariable. The functioning of the product and its value potential will thus be contingent upon the integrity of this interface.

But our case resists such a conception. The value of the design does not reside in the efficiency of one particular use, but in the affordance of many new uses. Nor is it optimized to a single type of user, because disability comes in great variety. Rather, it is made compatible with many uses and users, including those not known at present. Given the multiple problems of accessibility, the search for solutions became futile because of the wickedness of the problem. Each proposed solution made the designers aware of more aspects and concerns. The competition process turned from being a problem-solving process to becoming a learning process focused on understanding the problems themselves. This happened partly by design, but partly also by exaptation (Beunza 2007).

I will suggest that the project illustrates a way of creating new bounds of what we seek to know about. It is not bounds as such that are at issue, because we cannot know anything without bounds:

> *(…) we know by setting bounds to what we seek to know, and ignoring … what lies beyond.*
>
> (Loasby 2000, p. 4)

Because knowing is necessary for purposive human action (Loasby 2000), including the design of an office building, we need to make assumptions about the users, but not in the way imagined by Drucker and others. They define the users' projects, and they construct the scenes of use, as illustrated by the extensive instruction manuals that follow most tools and technologies. To know the value of some tool, we often set narrow bounds on the uses we enable and the users we create value for. But our case is different in the sense that it assumes that users with capabilities and needs construct their own individual scenes of use. Users are constructed as actively adding meaning to the environment, using whatever senses and reflections possible and deemed necessary to carry out their projects. The imagined users are confined not just to an environment of physical obstacles, but are exploring the meaning and affordances of the building. The purposive design thus aims to provide a richness of general affordances, serving as resources for everyone, but engaging the different faculties and senses of each individual user. When the designers decided to engage at least two different senses whenever possible, we realize that in many cases the affordances were redundant except in relation to specific disabilities. The number of instructions could be kept to a minimum by including a redundancy of other sensorial waypoints. This would also provide equal accessibility for the cognitively disabled users. The principle that any destination should be recognisable by at least two different sensorial clues (e.g. a colour and a scent) made the design resourceful even if one of the senses was redundant in most cases.

The imagined users were making active sense of the situation for their own purposes and using their own abilities. The design mobilized the multiple capabilities of disabled users, thereby enlarging the pool of potential users beyond what might be preferred in a rational and optimal design. The question was no longer how do we know, but how do *they* (the users) know? We need to define the world and social practices in order to know what to design; but in this case, the designers insisted (in our interpretation of their practice, but possibly also in their own) that the users would come to know through individual sense making. Rather than having such sense making be superfluous by offering specialized solutions that defined and exhibited the users and the uses, the rich ecology of physical traces and marks were designed to stimulate individual sense making and to guide it (and thereby the user) in the right direction, literally and figuratively. If affordance is both permission and promise (Latour 2002), designing accessible buildings is about giving all users an ecological space and giving them a role to play. They are no longer merely users of a physical structure, but constitute together a living ecology.

This transformation is what is innovative about our case. Knowledge and meaning are not given by design, something that can be packaged in a physical structure. Rather, they come out of the eventual and individual outcome of sense making that is occasioned by the interaction of people and things within the world's most accessible office building.

Conclusions

I set out to locate and learn about the concept of innovation, and I will now take stock of the results. It became clear that although the rhetoric of the competition did refer to innovation, the participants were busily occupied with designing an accessible office building and learning the intricacies of accessibility. It is my task to reinterpret what happened in terms of innovation.

In keeping with the Schumpeterian perspective on innovation, I will locate the innovative nature and summarize my findings in terms of three areas of qualitatively new combinations. First, consider the relationship between the *design task* and the eventual *building design*. In the design strategy quoted earlier, the proposed design is supposedly answering the questions of the client. The relationship is one between a problem and a solution, even if the solution may be a compromise and not resolve all possible issues of accessibility. But as a result of an intense learning process, such a relationship proved untenable. The 'problem' proved itself to be a wicked and ill-structured one for which no solution could be found. There is no way in which the design proposal could be deduced from the issues and concerns, because these issues and concerns posed irresolvable dilemmas and paradoxes. We can consider the proposed building design as a speech act, as another turn in an ongoing conversation, and the final proposal as merely the final turn before another conversation can begin. But it was an informed speech act, and also an esoteric speech act that depended on equally informed receivers for its intended meaning and effects. In this sense, the task and the design proposal became related as a signified is related to a signifier. Its qualities in terms of accessibility were tacit and made esoteric (i.e., inaccessible to most).

Second, consider the relationship between the *building* (as designed) and the future *users*. Ordinarily, we would think of this in terms of fixed interfaces between the physicality of the building and the 'designed' (i.e. presumed) needs and capabilities of the disabled users. However, in this case, the relationship was reconceived as *affordance*. The building was designed as an ecology of physical cues that could be made resourceful by self-helped users. It became clear that the innovation rested not on knowledge of the future use-value of the new design, but on the strategy of designing honest and rich affordances into the building. The users will be offered the possibility of making the building valuable and accessible, but with means and under conditions only partly determined by the design. Thus, the designed building offered use without making social exclusion a side effect. It offered a fertile ground for growing individual and new types of attachment. Affordances were such that they enticed the users to 'forget themselves as users,' and even the disabled users could act as 'professionals,' focusing merely on the purpose of their visit and the projected action. The building itself could be relegated to subsidiary awareness.

Finally, consider the relationship between the *design task* and the *designers*. Normally, we expect this relationship to be characterized by professionalism. That is, that the designers will work on the task with competence and knowledge, but without bringing their own role and identity into play. Yet that personal element was exactly what seemed to be injected here. In one formative episode – the eye-opening, experiential training course they were required to take – they became more personally present in a type of task that they had previously commanded professionally. This experience of being part of an experiment; this sense of suddenly becoming aware of one's ignorance about aspects of a realty previously taken for granted; these and other types of sensorial (even emotional) experiences reflected a new type of *attention*. This change of awareness, of focus, of attention may well be the most striking departure from convention. The minds of the designers were no longer set on finding solutions, but on discovering themselves as designers and attending to the very process of designing for accessibility (Hennion 2013). The competition for designing the world's most accessible office building made the participants experience themselves as learning individuals rather than as professionals, solution providers, and rational agents. Discovering themselves sensing a new world to be learnt, realizing the depth of a problem previously believed to be solvable, and mobilizing existing know-how and competences in a surprisingly directed exploration of the design task had profound effects on the motivation and roles of the participants. In this sense, just as the innovativeness of the design could be boiled down to a changed attachment of the users to the building as ‘professionals’, so the innovativeness of the competition could be boiled down to a change in the attachment of the participants to the design task as ‘amateurs’. By discovering themselves as designers, they were able to use their existing skills and competences to sense new aspects of the problem and the task – and thereby possibly to design a more sensibly accessible office building by developing an honest language of things that could aid users in becoming self-helped rather than reminding disabled users of their disability.

Returning to the usual connotation of innovation, we might look for it as a quality of the product, but should now realize how ambiguous the qualities of a product are. We might argue that the accessibility is measured in terms of benefits to the disabled user, but we now realize how much the value of the building depends on the user, not the building itself. We might look for the agency behind the innovation, but we now realize that innovations, in terms of reconfigured relationships, are not themselves decided and designed, but emerge as side effects of the focus on designing a new building. We might look for the knowledge that enabled the design to be made, but would now realize that the growing knowledge and experience of the designers made the design of accessibility more difficult, not easier. Yet this collective knowledge allowed the designers to turn the design into a meaningful speech act that implied and alluded to an informed understanding of the multiple and conflicting concerns and issues. Where we might have looked for the organized nature of the effort, we now realize that even if the design process were extensively planned and managed, the processes planned and managed were not the processes that reconfigured the relationships between the designer and the design task, the design task and the building design, and the designed building and its future users. These processes could not have emerged had they been anything more than occasioned by the organizing of a design and build competition.

The emergent reconfigurations were allowed to prevail in the competition jury and are now built into the physical office building. In that sense, the innovation is real, but we also saw how imperfect the competition between existing and innovative combinations is. The inaccessibility of accessibility to the uninitiated (and uninterested) decision maker or observer may introduce a systematic selection bias against original and innovative ideas merely because of oversight. Only thanks to the unusual bargaining power in the competition jury of a few initiated and interested clients was a fundamentally innovative design of accessibility given a chance to survive.

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4

Stakeholder Integration Champions and Innovation in the Built Environment

Gonzalo Lizarralde, Mario Bourgault, Nathalie Drouin and Laurent Viel

Introduction

A stakeholder approach – composing a broad view of stakeholders as suggested by Freeman (1984) – is of great importance in the analysis of innovation in the built environment. For Freeman and other theorists, stakeholders include both people acting on the project and those being affected by it. There is one fundamental reason for taking a stakeholder perspective on innovation: The built environment directly affects the population at large over the long term, even non-consenting stakeholders and people who have no say in the definition of the project or its implementation (Arnstein 1969; Campbell 1996; Forester 1999). Making this point even more relevant is the fact that construction projects are often prone to conflicts, delays and budget overruns, legal disputes and low stakeholder satisfaction (Koskela 2002; Koskela and Howell 2003; Walker 2007; Lizarralde et al. 2008). Such shortcomings become particularly problematic in the case of construction of public interest projects. These often include public facilities (e.g. schools, libraries, universities, hospitals) and urban projects (e.g. parks, public space, urban revitalisation). Although projects differ in some respects, notably in that they imply different intervention scales ranging from a building to a neighbourhood, they all include multiple stakeholders with divergent claims and interests. *Who* perceives the changes being developed during innovation processes as having value can become a key strategic issue for those involved in the projects, and a crucial concern for external observers interested in understanding the dynamics of projects.

However, we shall first clarify some of the characteristics of the context in which this value is produced and perceived. First, our contention is that

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value is created through two processes that are distinct but often interrelated: creation and innovation. Several authors argue that two additional processes are also required: adoption and diffusion (for example, Tangkar and Arditi 2004), and we will come back to these two processes later on. We know that the built environment is nourished mostly by customized buildings and urban projects that require significant creativity (it is a cliché that almost every building or infrastructure is a prototype), yet, ironically, the construction sector is often regarded as highly conservative and slow to change (Gambatese and Hallowel 2011). According to Winch (2003) and other authors, this is an unfair claim. They argue that innovations in this sector do exist but are rather difficult to identify because they do not conform to those that are easily measured by existing taxonomies, such as the one proposed by Pavitt (1984; Archibugi 2001).

Second, as pointed out also in other chapters in this volume, it has been found that innovation is highly dependent on intra- and interorganisational collaboration in several sectors including biotechnology (Powell and Cleveland 1996), manufacturing (Cuijpers, Guenter and Hussinger 2011) and in innovation project management (Adams, Bessant and Phelps, 2006) as well as in general business processes leading to innovation (Crossan and Apaydin 2010). However, the building sector in our view shows an ambiguous approach to collaboration. It delivers highly sophisticated products developed by temporary groups of specialised organisations, also known as *temporary multi-organisations,* or TMOs (Cherns 1984). However, the TMO members are brought together for only short periods of time; and thus, they barely have sufficient opportunity to establish the type of partnership agreements or collaboration cultures found in other industries such as aerospace or automobile (Pryke and Smyth 2008; see also Dubois and Gadde 2002, and the discussion in chapter 2 of this volume). Other barriers to innovation include the insufficient investment in research and development (Dulaimi et al. 2002), and the traditional fragmentation between professions and organisations in construction projects (Harty 2005). These barriers have led some observers to believe that the construction sector is far from achieving the levels of innovation found in cutting-edge sectors such as information technology and manufacturing (Toole, Hallowell and Chinowsky 2012).

Third, the creation of this value is affected by numerous factors that are beyond the direct influence of the construction industry and its traditional participants. In fact, municipal, regional and national regulations; economic and land policy; and institutional standards (rarely considered in what experts traditionally consider ‘the construction industry’) have a strong influence in the value (or lack of it) created in the built environment (Fishman 2000). This leads to the question of what can be considered a ‘construction innovation’, a question that requires a proper delimitation of this industry that does not actually exist. In response, we argue that the notion of a *built environment innovation* is more appropriate; this implies a new delimitation that expands the boundaries of the construction industry by embracing also the stakeholders and practices that are directly and indirectly *affecting* and *affected* by construction projects.

Fourth, there is arguably a tension between the value perceived by the construction industry and the value perceived by stakeholders external to the project or the construction industry. In fact, there has been a strong emphasis on the examination of the benefits of innovation for the construction industry and construction companies (Karim and Australian Centre for Construction Innovation 1999; Emmitt 2002; Barrett and Lee 2008; Brandon 2008). In a comprehensive study of innovation in small construction firms, Sexton and Barrett (2003a) found that practitioners consider that an *innovation* is the effective generation and implementation of a new idea, 'which enhances *overall organizational performance*' (emphasis added). They found that the principal motivation for innovation – and therefore probably the principal value that is perceived by them – is… survival.

Looking in retrospective, 'construction innovation' has not always translated into better cities, sustainable solutions, better buildings or superior quality of life for users. There are multiple examples of this. In fact, the list of polluting construction materials that were once considered a construction innovation is extensive – readers surely remember that the introduction of asbestos in construction facilitated the mass production of lighter materials but had fatal consequences for numerous users. It can be unfair to assess the value of these innovations with today's standards, but most analysts now agree that the building sector has considerably contributed to environmental degradation (Huovila and United Nations Environment Programme 2007; Kibert 2007; Ding 2008). For instance, the introduction of imported industrialised housing solutions in some developing countries has often had terrible consequences for the preservation of local construction methods, for the sustainability of future modifications made by users and for the local economy (Barenstein et al. 2010). Also, forthcoming research by Lizarralde and colleagues suggests that sustainability and resilience agendas in some significant cases may lead to unintended, ethically contestable outcomes. Of course, this does not mean that all technical innovations are dangerous or even suspicious; however, it highlights two relevant conditions. First, innovations that produce value for certain stakeholders (for example, construction companies) do not necessarily produce changes that are valued by end users or the society at large. Second, value is perceived as such in a very specific moment and context, and it is not a permanent attribute of the produced change or outcome.

Unfortunately, much of the work on construction innovation has focused more on *performances* (efficiency, efficacy, firm survival, market positioning, etc.) than on *ethics* (what is best and just for end-users, societies, nature). Sexton and Barrett (2003b) seem to recognize that innovation is increasingly linked to performance goals when they claim that

> *there appears to be an ongoing shift from viewing innovation as an 'end' in itself, to innovation being a 'means' to achieve sustainable competitiveness* (p. 615).

In terms of sustainable development alone, this approach has led to approaches that narrowly focus on technological solutions ('green gadgets') – often linked to reduction in energy consumption (Kibert 2007) and carbon emissions (Berardi 2012) with sparse references to other social, economic and environmental dimensions (Najam and Cleveland 2003 – see also the discussion regarding sustainability as a broader goal for construction innovation in Finland in chapter 13 in this volume). However, the emphasis on relying on technical changes to achieve sustainable outcomes has now been largely contested and is increasingly considered to miss the real problems that affect the environment and societies. Recent contributions argue that it is people's *attitudes* (or behaviours), not *technology,* that need to change in order to significantly reduce the relentless pressure on the environment (Dobson 2007).

Alternatives to a narrow, engineering inspired technological view of innovation are found in the literature. By building on innovation approaches proposed by Akrich, Callon, and Latour (1988), Rogers (2003), and Rowley and Sambrook (2009), it is possible to argue that innovation occurs when stakeholders distinguish a change in a product, process, organisation or service and *perceive in it* (this emphasis is important) sufficient value to adopt it or to adhere to it. There are two consequences of this improved definition of innovation in which the assertion of superior value in an objective sense is replaced with a much more tenable notion of subjective assessment of value: First, value is not an intrinsic and objectively given property of the change being realised. It is rather a quality that is perceived *by someone* within a certain context and timeframe. Second, given that innovation exists only if it is adopted or accepted, the larger the group of stakeholders who perceive this value, the more legitimate this change becomes (diffusion is thus a cause and a consequence of adoption and acceptance)

Stakeholder Integration Champions, Collaboration and Participation

Innovation and its frequent prerequisite, collaboration, do not emerge spontaneously in organisations (Hoegl, Weinkauf and Gemuenden 2004; Calamel et al. 2012). Since Schön's seminal work on the 'champions for radical new inventions' (Schön 1963), and reflecting the often uncertain economic incentives for innovation (see chapter 2 in this volume), we know that a leader (who can be an individual or a group) is often required to provoke and keep alive the activities and attitudes that enhance collaboration and innovation (Howell and Higgins 1990). These leaders receive different names, as authors play more or less emphasis on their roles in collaboration, integration and innovation. Their titles include 'project champions' (Gattiker and Carter 2010), 'integration champions' (Hartmann 2008), 'champions of technical innovation' (Howell 1990), 'green champions' (Bayraktar and Owens 2010), 'skilled conveners' (Mattessich and Monsey 1992) and 'relationship promoters' (Walter and Gemünden 2000). Yet they all have multiple common characteristics. They play a significant social role, enhancing relationships and communication *within* the organisation. They foster integration, facilitate communication, exchange information, identify expectations and capacities (Viel, Lizarralde and Bourgault 2013) and create the conditions for alternative solutions to emerge (Hartmann 2008). Sometimes they also help develop competences and behaviours *between* the organisation and other stakeholders (Tether 2002; Berchicci 2009), for example by creating interorganisational partnerships (Le Masson, Weil and Hatchuel 2006). Walter and Gemünden (2000) argue that champions:

> *identify appropriate partners of different organizations, bring them together, and facilitate the dialogue and the exchange processes between them. … [they] solve inter-organizational conflicts [and thus] fulfil an important social task* (p. 86).

We in this chapter refer to such actors as stakeholder integration champions (SICs).

Given the broad definition adopted in this chapter of stakeholders in public interest projects in the built environment, two main relationships between stakeholders can be distinguished: collaboration and participation. The former refers to relationships between stakeholders that share similar responsibility and authority (notably among professionals, participants of the supply chain or between professionals, clients and contractors). The latter refers to relationships between stakeholders that do not necessarily hold the same authority or responsibility, notably external stakeholders that do not participate directly in project design or construction, such as residents, users, neighbours, civil society and pressure groups (Viel et al. 2012). It must be noted that different forms of collaboration and participation exist. Some authors distinguish between *cooperation*, *coordination*, and *collaboration* (Kvan 2000). The degree of participation also varies according to the influence of external stakeholders on the decision-making process (Arnstein 1969; UN-Habitat 2009). However, most authors agree that collaboration and participation play a fundamental role in public interest projects, particularly for

> *widening stakeholder involvement beyond traditional power elites, recognizing different forms of local knowledge, and building rich social networks as a resource of institutional capital through which new initiatives can be taken rapidly and legitimately* (Healey 1998).

Keeping in mind the relationships between perceived value and innovation and the importance of collaboration and participation between stakeholders, we will in the remainder of this chapter consider more in detail, and on an empirical basis, which actors play the role of SICs in public interest projects in the built environment.

Method

Empirical data analysed in the following is extracted from a database of case studies conducted from 2007 to 2013. At the time of writing this text, the database contained 50 peer-reviewed case studies of architecture and/or urban design projects recently conducted in Canada (in the provinces of Quebec and Ontario). Studies were conducted by teams of graduate students over four- to six-month periods and were based on two sources of data. First, primary data included budgets, project reports, construction schedules, construction documents, photos and press releases. Second, observations and two to six semi-structured interviews held with project stakeholders. All case studies focus on the processes of conducting the project (this is the unit of analysis) and share a common structure of analysis that includes three elements: (1) the exploration of the process as a social system, (2) the exploration of the project life cycle and (3) the analysis of the costs, benefits and innovations involved in the project. These three constructs provide a basis for a rigorous analysis of (1) project process and management methods according to the nine knowledge areas proposed by the Project Management Institute (PMI 2013), (2) the characteristics and strategic objectives of the main stakeholders, (3) the project procurement strategy, (4) the project life cycle by phases from project initiation to transfer to the client, (5) the project's organisational structure, (6) informal relations between stakeholders and (7) the main issues affecting feasibility studies, including innovation issues and technical challenges.

As suggested by Proverbs and Gameson (2008), various information sources were used for triangulation, comparing printed data with qualitative information obtained from the interviews. The scientific strength of the case studies was supported by a peer review process in which an external expert and two reviewers assessed the reports and either suggested improvements or rejected the reports. These reviewers also validated that the studies conformed to the constructs proposed by the research project. The database includes only accepted and amended reports. It contains a wide range of projects executed within the last ten years and having different purposes (residential, education, religious), clients (private, public, mixed), funding options (private, public, mixed), interests (profit oriented, non-profit) and scales.

The identification of stakeholders that enhance innovation was conducted in three iterative steps. First, we identified a small number of examples, or projects, in which champions fostered collaboration and/or innovation. Second, we identified similar cases of champions that met the characteristics of those identified in step 1 (the first attempt at generalisation). We then consulted the organisations' websites and strategic plans in order to identify their core principles, mission and vision. Additional information used during this validation process included project reports and press releases that discussed the roles of these stakeholders in the project. Finally, we reviewed the list of examples identified in step one by interpreting the champions' characteristics in the light of possible generalisations. We repeated this process three times in order to derive the typologies presented here.

Creating the Conditions for Innovation in the Built Environment

Innovation in the built environment is highly dependent on institutional contingencies. National policy, urban regulations, construction codes, construction standards, market conditions and financial mechanisms facilitate or obstruct the emergence of innovative solutions. We found, for instance, that at least three developers in Montreal found their sustainable development innovations hindered by rigorous municipal regulations. However, our results also show that there is one fundamental human-related variable that permits to move from ordinary solutions to innovative ones capable of producing added value: stakeholder integration, including the participation and collaboration between stakeholders.

Construction clients obviously play a fundamental role in this integration. When launching the procurement strategy, they determine the most important structural characteristics of the temporary multi-organisation (TMO), impacting in this way on the distribution of roles for design, construction and management and creating the conditions for collaboration between designers, consultants and builders to happen. By holding primary decision-making authority, clients also create the conditions for external stakeholders to participate – or not. This observation echoes studies that have underscored the influence of the client in innovation processes (Brandon and Lu 2008; see also chapter 9 in the present volume) and of the procurement strategy and the client's organisational role in collaboration (Cherns and Bryant 1984; Nahapiet and Nahapiet 1985; Green 1996; Brandon 2008; de Blois et al. 2011). However, our survey shows that the innovation responsibility sometimes goes beyond clients, and calls for the participation of additional SICs. These SICs may be delegated by the client or may emerge naturally in order to integrate stakeholders. Different types of SICs operate in different manners within the TMO. Table 4.1 summarises seven types of champions identified, including the most representative examples of organisations and projects for developing the typology. A detailed analysis of these champions follows.

1. *Mediation partner*: This type of champion is a firm or non-profit organisation that accompanies the client and helps create conditions that are conducive to stakeholder collaboration and participation early

Table 4.1 Types of SICs in the built environment. Examples and projects studied for each type.

	Type	Example identified	Recent project
1	Mediation partner	Convercité	Benny Farm neighbourhood revitalization
2	Integrated client team	Non-profit Organisation in the Environmental Sector	Construction of the Maison du développement durable
3	Delegated project manager	Society Quartier International de Montréal	Quartier des spectacles urban project
4	Community support organization	Technical Resource Groups	Bellechase housing complex
5	Design integration team	Consortium de design	Construction of a sports facility in Notre-Dame-De-Grâce neighbourhood
6	Project integration team	Partenariat du centre d'activités d'Orléans	Construction of the Centre des arts Shenkman
7	Participation organizer	Office de consultation publique de Montréal	Extension of the Musée des beaux arts

in the process. This champion leads collaboration processes between community groups as well as stakeholders, professionals and the client in order to define project objectives and needs and mediate between them. This actor is less concerned with technical innovation or market adoption, and instead focuses on innovative ways of reaching consensus on project objectives and concerted solutions among heterogeneous stakeholders.

Example: Convercité is a non-profit organisation with significant competences to 'foster dialogue and cooperation through a flexible, yet rigorous approach focused on concerted action.' Its mission includes contributing to not only the project itself but also to the consolidation of the social environment around it, covering social aspects and the dynamics that drive them. This organisation is involved in complex urban challenges, sensitive subject matters or multi-stakeholder projects. It also coordinates the preparation of the site development plans and may support the client through the process of approving and obtaining municipal zoning changes. The organisation's activities include conducting census and data analysis, surveys and interviews and consultations with key stakeholders, including end-users, the community, and the client. This includes organising various public presentations and soliciting feedback from the community via meetings and websites (Convercité 2012). In 2006, the organisation obtained the Urban Leadership Award from the Canadian Urban Institute in the City Renewal category for the Benny Farm Task Force, a project that developed innovative responses to the challenges of sustainability and that was conducted through innovative processes of negotiation and mediation among diverging interests.

2. *Integrated client team*: Integrated teams are direct by-products of collaboration (an agent and an output of collaboration). This particular type of team is composed of several client organisations united into a single, complex project client. The team integrates several stakeholders in order to create a stronger project client capable of commissioning larger and more ambitious and innovative projects. By acting collaboratively with other partners (both financial and professional), this champion obtains additional resources and mobilises sufficient interest and expertise around the project, targeting technical innovations, and mobilising professionals and partners to create value in the process.

   Example: The Centre for Sustainable Development is a complex client composed by a number of non-profit organisations dedicated to promoting sustainable development. Together, the organisations developed a green building that exemplifies and showcases sustainable development practices. The team was highly involved in technical innovations, aiming at the highest level of certification for green buildings in Canada, which required greater integration between professionals and contractors (Centre for Sustainable Development 2012). Additional collaboration included a partnership with an engineering school in order to include integrated design practices and technical innovations in ventilation, energy system, water collection and others. The building has been awarded eight prizes and was nominated for the 2012 Elixir Award by the Montreal Chapter of the Project Management Institute.

3. *Delegated project manager*: This type of champion may be a firm or a non-profit organisation that acts as a partner and a delegated project manager of public entities (such as municipalities) in order to conduct major urban interventions and other public interest projects. This SIC seeks to integrate heterogeneous stakeholders and to develop a consensus around project objectives. Collaboration occurs frequently, whereby actors are invited to coordinate their objectives and needs. These champions identify stakeholders and develop tools and methods to facilitate communication between them. They participate early in the project and conclude their role when the project is transferred to the client. In this way, they serve as a pivotal information hub throughout the project life cycle. This champion often facilitates two types of innovation: (1) organisational innovation, by developing scenarios and collaboration methods in order to foster consensus on project needs and objectives and (2) technical innovation, by bringing various professionals and stakeholders to collaborate.

   Example: Society Quartier international de Montréal is a small-size organisation that provides project management services. Its mission includes catalysing public and private investment in public interest projects and managing all aspects of project management, from procurement to stakeholder management. The board of directors includes representatives from various partners, including the municipality, a public investor, a provincial ministry, and private stakeholders. This organisation is recognized for its experience in innovative collaboration methods that produce added value, such as ‘partnering’ and ‘visioning’ (Société QIM 2012). It is the co-recipient of 28 prizes in 14 different categories, including urban design and project management. Because of its recognized performance, it has been mandated to conduct five major projects in the city of Montreal, providing continuity to a series of innovative practices in collaboration and procurement.

4. *Community support organisation*: This type of champion, usually a non-profit organisation, acts as an intermediary between individuals or groups and public organisations that wish to develop social or community projects. They facilitate the development of socially and economically viable public interest projects. This SIC creates or consolidates the client organisation, for example, stakeholder cooperatives. In order to respond to significant affordability objectives (social projects face this challenge), these champions often create innovative process-related solutions for funding and project initiation.

   Example: Quebec’s Technical Resource Groups act as partners of the city and the government in order to implement housing programs (City of Montreal 2012). These champions contribute to the creation of housing cooperatives and accompany the project through the process of obtaining public subsidies and financial assistance. These champions offer technical support to conduct a ‘democratic’ process that integrates three levels: social development, real estate development, and financial feasibility (l'Association des groupes de ressources techniques du Québec 2012). This often means recycling existing buildings or adopting new technologies for reducing energy consumption. Process-related innovations also include innovative financial structures, collaborative methods, and architectural solutions that often differ from the profit-oriented solutions proposed by residential developers (Bâtir son quartier 2012).

5. *Design integration team*: This type of champion (also a by-product of collaboration) is not a single organisation, but rather a private design consortium created for the development of complex projects. Design consortiums seek to integrate professionals in order to respond to technical challenges and complex demands in tendering processes. However, the consortium's collaborative approach can also serve other purposes, including integrating stakeholder needs and creating value for them through technical innovations.

   Example: The design consortium involved in the construction of a sports facility in Notre-Dame-De-Grâce neighbourhood is composed of two architectural firms, a landscape architecture firm, a project management and engineering firm and a mechanical engineering firm. In a recent case, community groups opposed a project designed by the consortium because of its impact on a green area in the neighbourhood. In response, a committee to develop the technical project brief was created, involving the participation of local residents and the design consortium. The integration of heterogeneous but complementary specialists within one team facilitated the adoption of prefabricated components, the decision to build some parts of the building underground (to reduce the building's impact) and the decision to seek an environmental certification.

6. *Project integration team*: This type of champion is also a consortium of different companies, but in addition to design firms and consultants it includes other partners with financial, managerial, and construction capacities. These consortiums are usually created to respond to public-private partnerships (PPPs) or design-build contracts in which designers and builders work in concert under a single contract signed with the project client. These consortiums integrate (1) designers, builders and stakeholders having financial, legal and managerial expertise and (2) public and private partners. Consortiums often have multiple mandates that are unusual for most construction and design companies: to finance, transfer facilities, own and operate facilities or act as a land developer. Even though PPPs are not new and their performance has been largely contested in Canada and abroad (English 2006), they arguably adopt innovative managerial procedures and structures, for example, integrating data from operational activities, construction, design, financing, and so on.

   Example: The Orléans Town Centre Partnership is headed by Forum Leasehold Partners Inc.; it includes a construction company, an architectural firm, and engineering firms. Joint ventures are also created with other residential developers and builders for specific project aspects. Its role includes operating facilities and acting as a land developer.

7. *Participation organizer*: This non-profit type of SIC organises participatory public debates around public interest projects. Based on public consultation, its recommendations may strongly influence a project's approval. This champion does not facilitate collaboration per se. However, it does develop participatory mechanisms to give voice to all project stakeholders. The objective is to establish credible, transparent and effective consultation mechanisms for public interest projects. This champion does not facilitate technical innovations. However, it may set up public participation mechanisms (e.g. websites, forums, conferences) that are perceived as innovative by several stakeholders in other cities.

   Example: The Office de consultation publique de Montréal is a non-profit organisation that arranges public consultations for public interest projects. This champion encourages participation, facilitates citizen access to information and produces reports that provide recommendations for the municipality and project developers. It acts as an independent organisation, or a neutral third party, to liaise between the public, the city and developers (Office de consultation publique de Montréal – OCPM (2011)).

Integration for Innovation

The significance of integration of firms and organisations in a fragmented construction sector has been much debated, and the use of technology as a means to foster integration is discussed in chapter 11 in this volume. However, champions of integration in the built environment have not been sufficiently analysed and classified. Gambatese and Hallowell (2011) recognize them as 'innovation generating organisations', and Hartmann (2008) argues that they play a fundamental role *within* construction client organisations in creating awareness about possible innovations, translating innovative ideas, encouraging communication, coordinating activities and solving conflicts. We do not make the claim that our typology is comprehensive, but our findings echo these previous results and expand them to understand how SICs operate in order to produce innovation that leads to added value for a wide spectrum of stakeholders.

SICs are involved in the projects to varying degrees and phases in the project life cycle. SIC types 1, 2, 4 and 6 participate in all phases: initiation, planning, design, approval, procurement, construction and closing. In contrast, the participation organizer (type 7) intervenes to a limited degree, in the approval phase, when projects are subject to public debate, and the design integration team (type 5) acts mostly during the design phase when professionals get together to respond to the project brief. Except for type 7, all contribute to collaboration between internal stakeholders, whereas types 1, 3, 4 and 7 also facilitate the participation of external stakeholders. Although some facilitate technical innovation (2, 3, 5 and 6), others establish better conditions for process-related innovation (1, 2, 3, 4 and 6 and 7). Despite these differences, the contribution of SICs through the enhancement of different means of participation and collaboration leads to significant innovations in the program, organisational activities, funding alternatives and technical solutions. In these ways, they create added value to participating stakeholders. Instead of producing a result that satisfies one stakeholder (or a reduced number of them), SICs help achieve solutions that produce added value to a broader group of *affecting* and *affected* stakeholders.

There are five areas of expertise to which SICs contribute directly or indirectly in order to create added value and innovative solutions: organisational, financial, technical, design-oriented and managerial. Organisational expertise concerns the know-how required for consolidating organisational structures or developing more efficient ones. This expertise is particularly useful for consolidating or creating the client organisation (e.g. a housing cooperative). Financial expertise concerns the organisation's capacity to find additional resources for the project and to help the project client develop financial solutions (types 1, 2, 3, 4 and 6). This expertise is crucial for champions to help establish the client organisation (types 1 and 4). Technical expertise concerns know-how in construction, materials, infrastructure, building components, and so on. This expertise may apply to architectural or urban needs, and it helps integrate different specialists in technical problem solving (types 1, 3, 4, 5 and 6). Design expertise concerns technical expertise in architecture and urban planning, particularly for the planning and design phases (types 1, 5, 6 and 7). Managerial expertise particularly concerns stakeholder management competences and activities (types 2, 3, 4 and 6).

Integration is obviously the most important outcome of the participation of SICs. More often than not, this integration helps to bridge the gaps that exist between stakeholders' expectations and needs. Yet SICs have different rationales for selecting contributors and promoting integration between them. Some, including types 1, 2, 3, 4 and 6, assume this responsibility in order to increase the available resources for the project (e.g. obtaining grants, integrating sponsors, attracting donors and funding). Although all SICs may be concerned with project quality, some are particularly interested in facilitating integration in order to improve the quality of the final outcome (building or public project). This includes meeting strict environmental performance standards, increasing value through design quality or reducing energy consumption. We find types 1, 2, 3, 4, 5 and 7 in this group. Some SICs are particularly concerned with time efficiency and improved methods for increasing process efficiency. They include types 3, 4, 5 and 6. Sometimes the role of these champions is to increase project acceptability, notably by users, community groups, pressure groups and other external stakeholders (types 1, 3, 4 and 7). Finally, some (types 1, 2, 3, 4 and 6) aim to increase client satisfaction by contributing to develop a project that better meets clients' needs and expectations.

Conclusion

In this chapter, we have proposed the adoption of a stakeholder perspective on innovation. This approach benefits from an inclusive notion of project stakeholders, referring to both actors that contribute to project development and people who are affected by it. The approach also benefits from adopting a broader view of the built environment, putting less emphasis on the 'construction industry' alone. We believe that a built environment viewpoint that considers both acting and affected stakeholders is required, thereby avoiding the narrow scope of specific industry participants. A broader perspective leads to value taking on a different meaning, one in which short-term value for a minority needs to be compatible with long-term value for society at large, one in which ethical principles of what is *good* for the environment and *just* for stakeholders is balanced with performance objectives for the project or any single industry.

This viewpoint challenges the notion of value created by innovation as an objective or technological fact. We are calling for a consideration of sustainable value created for a broader group of stakeholders. Our empirical results reveal the importance of SICs *within* organisations and in building relationships *between* organisations that participate in temporary multi-organisations. The results show that, although project clients are the primary champions of integration, at least seven types of entities can act as complementary integration champions, enhancing innovation and value creation within the TMO. These SICs commonly contribute to establish collaboration between professionals and/or to increase participation by external stakeholders, balancing performance objectives with ethic responsibility towards the society and the environment. However, SICs differ in nature, objectives, and modus operandi. As such, they may place more or less emphasis on collaboration, participation, product innovation and process innovation. Their work varies according to the project phases in which they intervene with some champions limiting their contribution to a specific phase and others participating throughout the entire project life cycle. SICs pursue different objectives linked to value creation, such as increasing resources, improving quality, reducing delays and increasing the satisfaction of stakeholders. And finally, SICs may pursue profit or non-profit objectives and may contribute their own expertise to the project, placing more emphasis either on the quality and characteristics of the final outcome or on management processes and efficiency.

It is important to note that our study is limited to projects conducted in Canada. Therefore, these results cannot be generalised without considering patterns found in other studies in other countries. However, the results' transferability could allow for predicting and anticipating outcomes in other cases. Although the cases presented here do not cover all possible variations of SICs, they enable an understanding of how SICs influence the project process. Additional case studies are needed to explore other types SICs; however, the findings here have both practical and theoretical implications. For instance, they invite professionals to increase the scope of stakeholders affected by innovation processes. From a theoretical viewpoint, it balances a 'construction industry' approach concerned with technology-based growth with a stakeholder view of construction innovation more broadly oriented towards promoting a built environment attuned to concerns of human wellbeing and engaged with ethical objectives on a societal level.

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5

Grassroots Innovation in the Construction Industry

Martin Loosemore

Introduction

The World Economic Forum's Global Risks Report 2013 highlighted a future of complex and interconnected social, economic, environmental, geopolitical and technological challenges (World Economic Forum 2013). Innovation is crucial in responding to such challenges. Recognising this, individual countries are developing their own national innovation strategies. For example, in Australia, Culter's review *Venturousaustralia* (2008) called for a significant recasting of Australia's innovation policy, and in 2010, the Organisation for Economic Co-operation and Development (OECD) launched its innovation strategy to coordinate governmental approaches to national and global challenges, such as climate change, poverty and food security. Other regional initiatives include the KLEMS project on growth and productivity in the European Union and regional accords, such as the Lisbon Strategy, which are designed to address low levels of innovation, productivity and economic stagnation through various non-binding policy initiatives.

Business seems also to be increasingly convinced that innovation is crucial to its prosperity in an increasingly uncertain, dynamic and interconnected world. For example, in Australia, the influential McKell Institute recently published its report into the country's productivity and declared that firms must 'innovate or perish' (Green et al. 2012, p. 12). It claims that executives can either take the "low-road" of narrow cost cutting in an unwinnable "race to the bottom", or the "high road" of innovation engaging with the vision of a dynamic knowledge-based high-wage, high-productivity economy. The Grattan Institute has also identified innovation as a key area of

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reform and noted that innovation appears to be concentrated in a small number of 'persistent innovators' in high-tech industries, such as manufacturing, electronics and pharmaceuticals (Eslake and Walsh 2011). Firms that operate within the construction industry, whether they are consultants, contractors, subcontractors or manufacturers, are conspicuous by their absence from such lists. For example, the *Business Review Weekly*'s recent list of the thirty most innovative business firms in Australia includes none from construction. Here, as numerous authors have revealed, the broad response has been to work people harder and harder, and to transfer risk down the contractual chain to the point of least resistance, resulting in an industry that underinvests in its people and provides few incentives or resources to innovate (Tatum 1987; Lamborde and Sanvido 1994; Gann 2000; Loosemore 2004; Sexton, Abbott and Lu 2008; Brandon and Lu 2008; Ness 2010; Dainty and Loosemore 2013).

Grassroots Innovation

Joseph Schumpeter, one of the most influential economists of the twentieth century, is widely credited as offering the beginnings of an operational theory of innovation (Schumpeter 1976, 1983; see also the Introduction and chapter 2 in the present volume). Building on the work of Karl Marx, Schumpeter developed the theory of economic innovation and business cycles, identifying innovation as the critical dimension of economic change. In Schumpeter's vision of capitalism, technological innovation often creates temporary monopolies, allowing abnormal profits that would soon be competed away by rivals and imitators through a process of 'creative destruction'. Most developed countries still base their innovation policies on neo-Schumpeterian 'pipeline' models of innovation that reflect the type of linear, laboratory-based innovation that occurs in high-technology product-based manufacturing industries. However, contemporary innovation research has begun to question whether this model reflects the type of innovation that occurs in burgeoning creative and service industries, such as construction. For example, Taylor (2005) has argued that much of the innovation that occurs in sectors, such as construction, is invisible to the innovation metrics traditionally used to rank industries in many countries, and it is for this reason that they appear to underperform in comparison with other industries. In particular, it has been argued that neo-Schumpeterian notions of innovation fail to understand recent changes in modern business models brought about by an increasingly interconnected, dynamic and uncertain world. These changes have blurred the boundaries between service-based and manufacturing-based industries and called into question the effectiveness of highly planned approaches to innovation. Cutler (2008) recognised this problem, arguing that traditional government measures of technical innovation significantly underestimate the amount of innovation occurring in many industries, such as construction. In the UK, NESTA (2007) and Barrett et al. (2007) also highlighted this issue, arguing that there are fundamental differences between traditional science-based measures of innovation (patents, R&D expenditure and so on) and those needed to detect the type of 'hidden' innovation that occurs in service-based industries, such as construction. Hidden innovations differ in a number of important ways to the types of innovation detected by the traditional definitions. First, hidden innovations are generally driven by the need to respond to day-to-day problems in a real-life setting (such as a construction project), rather than some large, formalized R&D program. Second, hidden innovations do not generally take the form of new radical technologies but are based on adapting and borrowing ideas from elsewhere (reinvention) and by applying them to new problematic contexts (such as a new construction project). Third, hidden innovations do not tend to occur within the confines of one single organisation, but tend to be co-created spontaneously and often serendipitously in collaborative networks of manufacturers, consultants, suppliers, subcontractors, designers and clients. Fourth, suppliers and intermediaries tend to play a much larger role in stimulating, developing and diffusing hidden innovations than do government incentives and policies.

Barrett et al. (2008) also recognised the limitations of traditional neo-Schumpeterian thinking in the construction sector. They argue that this research has tended to focus on large enterprises and neglects to sufficiently consider the special innovation challenges faced by the many small- to medium-size enterprises (SMEs) that dominate the construction industry. Sexton et al. (2008) found that SMEs are motivated to innovate by different factors than large firms (survival rather than growth, and the need to solve immediate project-related problems). SMEs are also said to be more open and responsive to their market environment than large firms and rely more on personal client relationships and on the tacit knowledge and the experience of their employees. Typically, they are also less technology intensive, lack the 'slack' resources to innovate and are more highly geared than large firms. Barrett et al. (2008) argued that when one looks at the construction sector as a system of contributors over the whole life cycle of a building, it is clear that a much larger constituency of stakeholders need to play a role in the innovation process, compared with manufacturing. There are politics to be handled and many vested interests to be considered, which make the innovation process far more 'behavioural' than scientific. And in contrast to manufacturing, innovations are rarely large scale and radical in construction but small scale, incremental improvements in services or products. Innovation in construction also tends to be more ad hoc than in manufacturing firms, based on ideas from employees and managers developed incrementally 'along the way' in response to challenges during the service delivery process. As Gronroos (2000) shows, even when a service-based organisation develops a systematic and planned innovation process, innovations themselves must be developed by the people working in that organisation, often working closely in collaboration with customers as co-producers of knowledge. People with ideas then have to fight for the recognition of their ideas, and the business culture, climate and structure must enable these new ideas to rise to the surface; otherwise, these ideas will die and become wasted and lost.

So it is clear that while the construction sector has often been lamented for its lack of innovation or even for being 'backward' (Woudhuysen and

Abley 2004), a more informed view recognises the sector is missing an appropriate model to conceptualize and understand the innovation process. Indeed, even outside construction, traditional neo-Schumpeterian notions of innovation are being questioned by many business leaders who are becoming disillusioned with the low return on investment from their R&D activities (*The Economist* 2013). In response, many business leaders are adopting what is in this chapter called a *grassroots approach* to innovation. This approach seeks to harness the talents and experience of their workforce and to capitalise on their unique relationships with key business partners who may have previously been seen as 'outsiders'. Not only does this approach more closely reflect the way that innovation occurs in the construction sector, but it offers considerable potential in tackling the many challenges that face contemporary business and society.

The Elements of Grassroots Innovation

The grassroots approach to nurturing, generating and capturing innovation is based on accumulating evidence that 'planned' approaches that seek to 'systemize' innovation need to be balanced with flexible strategies that can harness the largely untapped unpredictable and serendipitous opportunities offered by an increasingly uncertain and interconnected world. As Clegg et al. (2011, p. 33) point out, there is element of unpredictability, luck and happenstance in the fabric of all organisations that needs to be better understood for which current models of strategy are inadequate. According to Hamel (2002), in an increasingly networked, complex and dynamic business world, innovation is much more likely to arise out of serendipity and happenstances than from any formal planning process. So rather than try to eliminate this uncertainty, we should accept it as an inevitable and learn to manage it. A grassroots approach to innovation also recognises that innovation is increasingly 'social'. According to Muir (2000), innovators do not live in straight lines but in a 'zig-zag', with random interactions, casual conversations and serendipitous encounters. Innovation depends on relationships as much as it does on facts. The importance of 'community' is further reinforced by recent research into industry innovation clusters, such as Silicon Valley. According to Horrigan (2011, p. 21), people working in firms located in such areas 'come into contact with each other without really understanding what the other is doing, yet they discover than one has the solutions to the other's problems'.

The idea that success depends on our relationships with others rather than on individual attributes will require a fundamental change in management thinking. As Clegg et al. (2011) point out, much of what we have been taught about 'good' management comes down to competition, top-down strategy and individual factors, such as talent, attitude, intelligence, education and hard work. Clegg et al. (2011, p. xxiv) argue that traditional strategic thinking emerged 'as a macho, testosterone-charged younger brother of economics' and provides little insight into how managers might work in this way. Isolated from advances in sociology, organisational theory and political analysis, Clegg et al. argue that good strategy has been assumed to arise from the inspirations of great individual leaders. However, future approaches to strategy will need to be 'constituted and enacted organizationally' and in collaboration with stakeholders (pp. xxiv). Muir (2000, p. 24) sums this up nicely when he states that managers will need to shift their paradigm from 'living in little boxes' to 'living in networked societies'. New communication technologies ensure that information is more dispersed than ever before and that firms must learn new skills to enable them to tap into multiple and more informal sources of information that are often contradictory and constantly changing. For Hagel, Brown and Davison (2012), one of the critical defining factors that distinguish innovative companies is their socially imbedded management practices that build and harness loosely coupled business networks to provide scale without inertia. These business networks drive learning, capability building and performance improvement by enabling people to learn faster. Locke and Spender (2011) argue that in the most successful firms, these networks are often based on deep and trusting personal relationships and their members are drawn from diverse backgrounds. It is the intersection of different knowledge domains that firms will find the solutions to tomorrow's new challenges.

This grassroots view of innovation moves us beyond the simple dualistic problem of whether innovation is supply pushed or demand pulled. The grassroots approach argues that innovation is not an individual act and does not just happen within the industrial supply side or as a result of the articulation of user demand, but through a complex set of processes that link many different actors together. It also proposes that innovations will tend to occur at the boundaries of organisations and often in serendipitous unplanned ways. This challenges early ideas that conceived innovation as a deterministic process. Instead, innovation is seen as a socially constructed phenomenon arising out of many conscious and unconscious 'choices'. In other words, innovation does not necessarily emerge by following a predetermined logic but through many possible paths. As Wenda, Croissant and Restivo (2005) point out, there is a 'mutual shaping' of new ideas by firms and society, a principle that aligns with contemporary theories of open innovation, user innovation, cumulative innovation and distributed innovation, all of which argue that innovations are co-created in collaboration between firms with highly permeable boundaries, enabling the transfer of knowledge between the firm and a world of widely distributed knowledge (Chesbrough, Vanhaverbeke and West 2008).

Grassroots Innovation in Practice

It is all too easy to criticize traditional planned approaches to strategy at a conceptual level but much more difficult to translate these concerns into alternative practical ways of organizing. What does grassroots innovation look like in practice, and how does it work?

Organizing Around Opportunities

In answering this question, the work of Eisenstat et al. (2001) and Samson (2011) is useful. Their analysis of leading companies, such as Citibank, IKEA, 3M, Apple, Procter & Gamble and IBM, shows how these businesses encourage people in lower reaches of their organisations to show initiative and contribute to future strategy. Rather than viewing their businesses as a portfolio of business units, these companies view themselves as a flexible portfolio of resources that they can bring to bear on the most promising opportunities in their sector. In these decentralized opportunity-based firms, quasi-autonomous business units are connected by a corporate centre. Resources from multiple business units are not held in silos but are organised around emerging opportunities in different parts of the corporation. Through strong innovation-focussed strategy and leadership, opportunity owners are authorized through central screening to mobilize whatever resources they need, allowing these very large firms to emulate the market responsiveness of start-ups while capitalising on the advantages of their scope and scale. In this way, individual entrepreneurs look for opportunities that cut across different business units and that integrate the business as a whole. This organic structure constantly shifts in response to opportunities, and business development managers move relatively independently, seeking and leveraging new project opportunities by bringing cross-functional teams together from across the business. These companies have a matrix structure and employ a number of fluid 'opportunity units' supported by a host of stable 'resource units' in order to tackle specific projects. These ideas resonate with Kao, Green and Larsen (2009) and their research on construction competitiveness within regional contracting firms. These studies illustrate the importance of decentralised structures that enable multiple business units to exhibit entrepreneurial behaviour. Sustained competitiveness was found to depend upon the extent to which decentralised business units enact ongoing processes of localized learning and develop capabilities that transcend organisational boundaries such that they become situated within complex networks of relational ties.

Utilising Corporate Identity

Authors such as Cummings (2005) point to accumulating evidence that the world's most innovative companies use their corporate identities to inspire strategic differentiation. This approach not only inspires difference but builds legitimacy, authenticity and loyalty with clients, because strategic initiatives are seen to be aligned with corporate values and to be sustainable in the long term. However, whereas a strong and clear corporate identity appears to be important in driving innovation, the jury is still out on the exact nature of this relationship. For example, recent research indicates that some degree of ambidexterity may benefit organisations (He and Wong 2004). It also recognises that multiple identities (for example, those in different geographical regions) are inevitable and necessary and might actually foster innovation rather than stifle it. The basis of this argument rests in the diversity of perspectives that multiple identities can provide. Also, whereas multiple corporate identities can cause confusion, they can generate creative tensions, afford flexibility and provide a wider vision in identifying and responding to business trends. A third possible benefit is that organisations may have the capacity to meet a wider range of stakeholder demands.

Taking an Emergent View

It has been known for some time that successful firms have both formal/planned and informal/fuzzy elements to their business strategies. According to both Mintzberg (1980) and Hubbard et al. (2002), successful firms do not stick slavishly to what they said they were going to do. They recognise that the future cannot be planned in infinite detail and that they need to be constantly sensitive to new knowledge and respond quickly to convert it into business opportunities. It is interesting to note that Hillebrandt and Cannon (1994) found that the strategies of construction firms have a very important emergent dimension. Managing a construction company successfully involves a constant opportunistic juggle to match human resources and management skills to a constantly changing array of geographically dispersed projects over time. Green et al. (2006) also found that construction firm strategy is more often emergent than pre-planned, shaped by unexpected opportunities and by individuals' often maverick behaviour. This suggests that the strategic flexibility to innovate already exists in the construction sector. However, rather than being driven by the need to innovate, this appears to be a function of the industry's need to organize within an uncertain project-based structure. The challenge for firms in the construction sector is to put this natural advantage to good use in driving more innovation.

Being Inclusive

Werbac (2009) argues that one of the main limitations of traditional models of strategy is that they neglect the critical role of social engagement and stakeholder interactions in the strategic decision-making process. Senior managers are not as rational and logical as traditional approaches suggest. Instead, in analyzing and responding to the future, managers appear to be influenced heavily by political forces, are more closely connected to lower operational workers than has been assumed and are not as aware of their business environment as implied by traditional models of strategy. Indeed, lower-level managers are often more in touch with the business environment than are senior managers, affording them access to important ideas and knowledge about the future that top managers do not have. In summary, contemporary strategic thinking sees innovation as an inclusive process that facilitates the opportunistic synthesis of ideas from all organisational levels.

Developing Unique Resources

The resource-based view (RBV) of a firm focuses on creating competitive advantage in the market by building unique 'imitable capabilities' and 'core competencies' based on its unique resources (Prahalad and Hamel 1990). A firm secures competitive advantage in the long term by having 'dynamic capabilities' in managerial and organisational processes that allow it to innovate to adjust these core competencies and resources to market changes (Teece, Pisano and Shuen 1997). The value of the RBV in construction was recognised by Barrett et al. (2008). To them, the potential for innovation does not come from the unique resources a firm owns but from how it uses and develops them to drive innovation. Barrett et al. (2008) argue that the proactive 'resource-push' view of innovation offered by the RBV (when firms innovate because they can) provides a more stable grounding for innovation in the construction sector than the dominant reactive 'market-pull' orientation (where firms innovate because they are asked to do so by clients). As Brandon and Lu (2008) argue, relying on clients as drivers of innovation is a 'cop out' by the industry and discourages firms from investing in their own new ideas and from acting out their shared responsibility for the advancement of the industry.

Collaboration

According to Horrigan (2011), organisations will in the future increasingly work in corporate 'swarms' that form quickly, attack a problem or opportunity and then quickly disband. In contrast to traditional notions of teamwork in which people may have had long-standing and stable relationships over time, swarms will be characterized by loose connections and weak ties. And rather than being driven by business, they will be formed by individuals using social media to create personal social networks and will be characterized by a certain degree of unpredictability that will be outside a manager's control. Indeed, these new business networks do not need to physically exist but can be virtual organisations enacting their activities and culture in cyber space. As research into informal networks in large organisations, such as ExxonMobil and GM by Bryan, Matson and Weiss (2007) found, firms have dozens if not hundreds of informal networks that rarely reflect dictated communication routes in formal organisational charts but that form and shift constantly as a result of the voluntarily activities of employees. (See also the discussion in chapter 8 in the present volume.)

de Man et al. (2008) argue that smart managers will learn to use these constantly shifting networks to leverage opportunity. However, few managers understand how to do this and, in reality, are able or willing to expose their businesses to the chaos (albeit potentially creative) that serendipity brings. When left entirely to themselves, informal networks can become highly dysfunctional, presenting new complexities, muddling roles, intensifying politics and presenting invisible risks to an organisation.

Leveraging Social Capital

Innovation is no longer an individual matter but depends on the quality of corporate relationships with other firms and the value that resides in these relationships (a firm's 'social capital'). *Social capital* refers to the value imbedded in a firm's social networks (Burt 2005). Social capital differs from traditional sources of capital in the sense that it is intangible and tacit, is located outside the business in relations with others and is not owned by any specific firm. Furthermore, a firm's social network does not translate automatically into social capital. Rather, it is the positioning of a firm in its social network and the nature and quality of its relationships with others in that network that create its social capital. Research in the field of social network analysis specializes in understanding what types of positions and structures afford most social capital to a firm or individual. This research has shown that certain network positions, particularly those who are 'central' or located 'between' others, derive the most power from their social networks (Brass 2003). Dodgson, Gann and Salter (2005) also recognise the importance of brokers in the innovation process by referring to the critical importance of 'T-shaped' people in organisations. These people facilitate the co-creation of new ideas through their in-depth knowledge of specialist areas and their ability to integrate it by brokering connections between different business units.

Assessing the Potential of Grassroots Innovation in Construction

What potential do the practical representations of contemporary grassroots innovation described above hold for construction? How realistically can these ideas be implemented in the construction industry and what potential benefits do they hold? To make but a preliminary empirical test of the ideas sketched in this chapter, interviews with thirty-five senior executives and government advisors were conducted. Without entering into a full and systematic analysis of the data, selected statements from these interviews are quoted in the following for purposes of illustration only.

Informants had positions distributed across the construction industry supply chain and had been recognised nationally and by their peers as being responsible for driving innovation across the Australian and UK construction industries. Responses from these executives and advisors indicated a general consensus that it would be easy to post-rationalize a grassroots type approach to innovation. As one respondent said, 'entrepreneurs are egotistical and will tell you about the culture they created after the event …'. There was a shared sense that innovation involves stress, hardship and discomfort, and that the ideas presented underplayed this pain another respondents statement that 'you can't comfortably innovate'. There was also a general consensus that constructive discomfort is best generated in situations where people are 'having a project to win, a problem to solve'. Furthermore, responders indicated that 'a cause that people can rally around is important'. Having a formal innovation strategy was widely thought to be irrelevant to catalyzing innovation, without a project to bring it to life: 'Innovation won't happen if someone simply dictates that it will happen'. Having a focus and a reason to innovate provides the thirst for knowledge that drives innovation: 'it opens your eyes and encourages you to go looking for new ideas…'. 'Our eyes are open when we are tendering… that's when most innovation happens. When we have got the job, the pressure is off and innovation becomes more reactive in dealing with onsite issues'.

So the idea of organizing around opportunities that is very prominent in grassroots innovation thinking is something that respondents recognised. Most of the innovations respondents described arose out of necessity: either of winning a job by adding extra value or in solving an immediate problem on a project. There was also general agreement among these executives and advisors that the industry has a comparatively short-term strategic horizon compared with other industries because 'most companies focus on the incremental operational innovations and the big game changing innovations that provide competitive advantage are few and far between… it's hard to think of them in construction'. There were numerous reasons put forward for this, including 'the fundamentally dysfunctional subcontracting model which assumes that they will innovate', 'the longstanding lack of investment in training and skills development', 'the cyclical construction market' and 'innovations tend to be restricted to individual projects'.

There was also consensus among our informants that innovation depends more on leadership than having a formal innovation strategy. As one respondent said, without leadership 'innovation doesn't get an agenda or quantum' and 'is directionless'. Furthermore, because innovations often challenge existing power structures and 'step on someone's' toes', leadership is considered essential to impose the authority to overcome that resistance. However, most believed there was a somewhat romantic vision of the innovative leader in the literature, whereas 'in reality they are hard nuts, egotistical, arrogant and determined'.

Although the concept of inclusivity and integration was widely considered as critical for innovation, many agreed that the ideal of integration is often unachievable in practice and that it is important not to lose sight of the need for business accountability. As one of the respondents said in criticizing idealistic notions of integration, 'One of the big mistakes people make in pursuing integration is to assume that one has to abandon accountability in the pursuit of trusting and open relationships'. It is critical that in pursuing innovation and interpreting much of the literature in this area, ideas from other sectors must often be tempered by the reality of the construction industry. The imposition of a completely loose system onto an industry that is by some seen as 'fundamentally dysfunctional' could potentially create more problems that it would solve.

According to the respondents, collaboration was also widely seen as crucial to innovation: 'it's very rare for successful innovators to work in a vacuum'. 'Collaboration is critical to get ideas across the line. The more people you can take the better'. However, when talking about collaboration, there was also some cynicism: 'Collaboration is just a word… there is nothing new in this… what it really means is that innovation comes from activity… activity spurs mutation… if there are more people working together on something then there is a greater chance of new ideas happening'. In construction, competition was widely seen as a barrier to collaboration: 'you can lose that competitive edge if you involve subcontractors too early. It can cause you to lose the job'; 'collaboration in construction is a huge challenge. There is always a sense that one is giving away something. The industry is so competitive that collaboration between the few big firms is almost impossible'. One of the reasons for this was understood to be the largely redundant role played by clients in the innovation process. Although clients have been identified by many as critical to innovation in construction (see, for example, the discussion in chapter 9 in the present volume), the dominating feeling among our informants was that most construction clients are not open to innovation or prepared to pay for it: 'Most clients are completely irrelevant to innovation. They have no interest in it what so ever. Unless of course it can reduce costs… then they have a great desire for innovation'.

Although the idea of organic structures was recognisable to most of those interviewed, there was also widespread agreement that there was a danger of being utopian in assuming a world in that businesses are too frightened to actually innovate. As one respondent argued, 'at the end of the day delivering projects is a highly pragmatic endeavor that requires detailed planning and strong accountability, discipline and reporting lines'. However, whereas the need for planning and control at the project level was recognised, there was also a strong sense of a need for decentralization at a business level. Innovative organisations seek to ensure that people are 'highly visible' and that there are opportunities for anyone to contribute ideas to make the business better 'no matter what role they play in the business'. These companies seek to create an environment in which there is a culture of talking and people are empowered to solve problems by thinking outside the square and challenging the norms. In these firms, it would that senior people are highly accessible and there is a chance for people with good ideas to 'figure out a role for themselves in the business' and to build new business opportunities around their personal interests.

Conclusion

In this chapter, we have criticized traditional neo-Schumpeterian 'pipeline' models of innovation that put great emphasis on scientific and technological research, and the idea that the transfer of ideas and technology from science to business is essential for construction innovation. Instead, a grassroots approach to innovation has been proposed. This should reflect more accurately the way that innovation happens in the construction sector. A first testing of these ideas against the insights and experience of some of the industry's leading thinkers in Australia and the UK supports the notion that innovation in the construction industry is enacted in a way that aligns strongly with Clegg et al. (2011, p. 33) and their observation that innovation occurs as much out of necessity as from any formal planning process. Rather than uncritically adopting notions of innovation espoused in much of the innovation literature as being systematic, research-based and preplanned, it may be more useful to adopt a grassroots approach that recognises that construction innovation is more opportunistic, reactive and socially embedded. The findings also resonate with Locke and Spender's (2011) ideas that innovation in construction does not necessarily emerge by following a predetermined logic but in response to opportunities. Whereas collaboration is difficult in practice, our findings concur with de Man et al. (2008) and their conclusion that innovative organisations learn to use constantly shifting networks to leverage opportunity better than competitors do. In other words, and aligning nicely with the network perspective on innovation presented in chapter 7 of this volume, innovation in construction is more a function of the relationships a firm has than the internal resources that it commands. As Samson (2011) showed, decentralised and flexible structures tied together by strong leadership and a strong corporate culture and identity are essential in such environments. Our discussion also lends support to the assertion of Hubbard et al. (2002) that to be innovative, little is achieved by way of formal innovation strategies. Finally, the findings here strongly support the research of Hillebrandt and Cannon (1994) and Green et al. (2006) that found that strategy in construction environment is more emergent than preplanned, shaped by unexpected opportunities and the need to win work.

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6

Regulation and Innovation in New Build Housing: Insights into the Adoption and Diffusion of Micro-Generation Technologies

Carl Abbott, Martin Sexton and Catherine Barlow

Introduction

In the loosely coupled constellation of heterogeneous sectors that design and produce our built environment, many kinds of value are created. Consequently, innovation – which here is understood as transformation of established ways of creating value, as discussed in the introductory chapter 1 – occurs in many different ways. An important source of innovation is the creative problem solving that occurs inside projects and firms (as argued in chapter 5). Another source – or trigger – of innovation is discussed in this chapter; it composes the evolving institutional framework within which actors in the construction sector, notably building regulations and standards, are embedded. Hitherto, research into innovation and regulation in construction has tended to focus on what is going on at the level of a product or a firm. Although significant research exists that helps understanding innovation processes at the project level, for example using a complex products systems approach (Winch 1998; Gann and Salter 2000) or an innovation value chain perspective (Ozorhon et al. 2010a, b), relatively little work has focussed on the real-world complexity of the roles of individuals in the process of negotiation in the face of regulatory norms and practices. This chapter seeks to address this issue, through research that illustrates the complex series of interactions within house building projects, and gives new insights into what is a crucial policy area.

In the UK, the residential sector is responsible for 16% of CO_2 emissions (DECC 2014). Cuts in demand for gas and other hydrocarbon fuels are essential if carbon reduction targets set by policy makers are to be met. The use of so-called micro-generation technologies (MGTs) can play an important role, and to this end a portfolio of government policies have been

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Table 6.1 Key Microgeneration Technologies for New Housing

Technology	Electrical Power	Heat
Biomass boilers		✓
Solar photovoltaic arrays (PV)	✓	
Solar thermal (hot water)		✓
Wind power	✓	
Ground source heat pumps		✓
Air source heat pumps		✓
Other heat pumps		✓
Micro-hydro	✓	
Micro combined heat and power (CHP)	✓	✓
Renewable CHP	✓	✓
Hydrogen fuel cells	✓	✓

Source: Based on Fisher, J., Jessop, C., McGuire, K. and Waddelove, A. (2008), *A Review of Microgeneration and Renewable Energy Technologies*. Watford: NHBC Foundation and BRE Press.

enacted to encourage house builders to develop low carbon homes. Policies that incorporate adoption and use of MGT and of improved fabric solutions to meet carbon reduction levels is, in effect, an environmental innovation policy.

The intent of this innovation policy is clear, but what is its impact on practice? Generally, the development and widespread diffusion of MGT in the UK are seen as part of the drive to lower CO_2 emissions as well as contributing to addressing issues of energy security, fuel poverty (where household income, taking into account energy costs, falls below the poverty line [DECC 2013]) and competitive markets (DTI 2006; Element Energy 2008).

Micro-generation is defined here as the "onsite generation of low- and zero-carbon heat and electricity in domestic, public and commercial properties" (Bergman and Jardine 2009, p. 6). Although other types of MGT exist, the National House Building Council (NHBC) in the UK identifies the MGTs in Table 6.1 as being most relevant for incorporation into new houses (Fisher et al. 2008). The optimal choice of MGT varies with the type of housing development and broader institutional context; there is no generic 'best' solution. To give but one example, the MGT solution for a high-density apartment development in a city centre may be different from a low-density housing development in a rural area. For the purposes of the analysis presented in this chapter, the three key micro-generation technologies investigated were those most frequently adopted: solar thermal, solar photovoltaic (PV) and air source heat pumps.

The research questions that this chapter seeks to answer are these: How and why do house builders interact with planners, supply chain partners, and end users to deliver MGT solutions? How does the current market and regulatory context shape this interaction? Finally, how does this interaction shape the strategy and practices of the house builders and the incorporation of the MGTs in housing designs? Key actors and organisations are identified, and their different understandings of and expectations towards the new technology are explored.

The socio-technical network approach was adopted to explore these research questions. Central concepts of this approach include the following:

- *Nodes:* Nodes in the network can be considered to be either individual human actors or (representations of) groups of human actors.
- *Intermediaries:* These are anything that passes from one actor to another (e.g. documents, conversations, money).
- *Interpretative flexibility:* Individual actors' interpretation or meaning attached to a given artefact or technology. Different actors may have very different interpretations of the same artefact. These differences may stimulate controversies and negotiations between the actors until (in an ideal situation) the technology stabilises and closure is achieved.

The approach employed here enabled the research to focus on the relations between the principal actors in the development of technological solutions (for example, statutory bodies such as local planning authorities, house builders and their supply chain partners). The method involved an initial identification of key actors, that is, the stakeholders involved in the selection and deployment of the MGT in question. During data gathering, interviews focussed on the decision to adopt a particular MGT, the actors' understanding of the MGT, and the problems experienced during adoption. Questions about the decisions included the range of stakeholders consulted, types of issues considered relevant, the knock-on effects that the adoption of this technology was expected to have on the supply chain and established practices. In total, nine case studies were developed, six rather typical cases of UK housing developments and three cases in which the most commonly used micro-generation technologies were being used. The data collection included interviews with the most relevant actors, review of pertinent company documentation and observation of several design and production meetings on the live projects. The data was analysed using qualitative content. Special attention was paid to the uptake of MGTs, their effect on routine design and procurement processes, stakeholder engagement and the creation of new knowledge. Although a full analysis of these case studies is being undertaken, this chapter focusses on one particular case study.

Regulation and Innovation for Sustainable Building

It has often been said that construction is the most regulated of all industries (for example, Morton and Ross 2008, p. 202). This specificity of construction makes the understanding of the link between regulation and innovation particularly important. The adoption of MGT in new house building is driven by regulation; through planning law, Part L of the Building Regulations and the Code for Sustainable Homes (CfSH). Definitions of regulation emphasise a balance (Baldwin and Cave 1999) or a discrepancy (Kemp et al. 2000) between private, market-based activity and public interest when regulation intervenes on behalf of society to generate desirable communal outcomes. Baldwin and Cave as well as Kemp et al. quote

Selznich's definition of regulation as 'a sustained and focussed control exercised by a public agency over activities that are generally regarded as desirable to society' (Selznick 1985). The UK government's definition of regulation as 'a rule with which failure to comply would result in a business coming into conflict with the law or being ineligible for continued funding' (BERR and DIUS 2008, p. 10) emphasises the legal obligation of compliance with such regulation. House builders therefore face a legal obligation to improve the environmental performance of their new build housing designs.

Research into construction regulation includes both socio-economic (Banfill and Peacock 2007; Winch 2010) and technical regulation (Gann 2000; Winch 2010). Socio-economic regulation defines what can be built and where. It is characterised as the planning system, whereas technical regulation defines the standards for the constructed end product (such as housing) and is enacted through building regulations. Both the planning system and building regulation regimes have an impact on the design phase in the production of new housing.

The effect of regulation in general and environmental regulation on innovation in housing in particular is contested. Oster and Quigley (1977) showed that prescriptive US building codes provided regulatory barriers to the diffusion of innovation. Opponents stress that environmental regulation increases production costs and reduces the profitability of firms exposed to it (Romstad 1998). In the UK, regulations are 'viewed by many designers and builders as an additional burden' (Gann, Wang and Hawkins 1998, p. 280) rather than as a promoter and enabler of innovation. For example, the Home Builder's Federation has claimed that 'the cumulative impact of regulatory burdens on home builders has reached a tipping point…our industry cannot be viewed as a sponge able to soak up every additional cost thrown at it' (Baseley 2008). This is indicative of an industry view that the achievement of broader policy objectives, such as environmental sustainability, should be the responsibility of government, not commercial business whose primary concern must be to maximise profit for shareholders (Baldwin and Cave 1999; The Callcutt Review 2007).

Proponents of environmental regulation such as Roediger-Schluga (2003) argue that regulation can lead to the discovery of new areas of product development, to a search for relevant processes in different fields of technology, and to the acquisition of new, complementary knowledge and capabilities by firms. Furthermore, the move towards more performance-based regulation has tended to demonstrate that the regulatory process could stimulate the benefits of change, information sharing and cooperation between public and private sectors, but also that 'The PBB approach… is … too focused at the building level and … unreflectively assumes that relevant actors have the capacity, ability and motivation to innovate at a business level' (Sexton and Barrett 2005).

The tension between the additional costs and increased burdens imposed by regulation on the one hand and the need for the development of innovative products and practices on the other is well illustrated by the CfSH and associated regulation. Achieving various code levels by generating points to reach thresholds represents a flexible performance-based regulation.

However, the 'radical changes to construction methods and practices' and the 'evolution of a new architectural vernacular' implied by the code (Banfill and Peacock 2007) imply innovation beyond the generally low level of innovation normally associated with housing construction. Although the aspirations of the code were considered to be both 'admirable' (Banfill and Peacock) and 'ambitious' (Osmani and O'Reilly 2009), the cost of meeting the policy objectives fell upon the house building sector. Thus, many in the industry considered both unreasonable and unfair.

The adoption and diffusion of MGTs has been, to date, largely driven by the implementation of the CfSH and associated regulation. It will be phased out as part of the UK Government's Housing Review with requirements pertaining to energy, for example, being embodied in Part L of the Regulations. The impact of the CfSH will be felt, therefore, indirectly in the new building regulations. In addition, the CfSHs will directly impact on land that has been given planning permission with code requirements, but has yet to be developed. The CfSH set out six levels of performance from level 1 through to level 6, where the latter is defined as a 'zero-carbon' standard home. Micro-generation is a possible part of house builders' solutions to meet particular code levels on any given development. The code itself is voluntary, but local councils can require developers to comply with it by including the requirement in their planning policy. Affordable housing that is funded by the Homes and Community Agency (HCA) is required to be built to code level 3, the energy standard that is now incorporated in building regulations. The code therefore works with the UK government's Zero Carbon Policy that beginning in 2016 requires all homes to mitigate through various measures all the carbon emissions produced on site as a result of regulated energy use. Against this context, an important aim of the research reported in this chapter was to explore the range of factors that currently support (or hinder) the adoption of certain MGTs in certain types of development and the effect of broader institutional conditions on that choice.

The CfSH and associated policies and regulation present profound technical challenges that are currently being explored. However, less is being done to develop knowledge on how the specificities of the code and related policies influence technology development processes and practices associated with sustainable home building. Shields (2005, p. 19) notes that construction innovation research has a tendency to focus on the 'on site activity' rather than on the surrounding institutional framework. Gann (2003) notes that regulation does not necessarily drive innovation *in ways of working* (process innovation in building). His argument is that project management is not normally subject to regulatory conditions. Much of the regulation surrounding the design of new housing concerns the socio-economic definition (Winch 1998, p. 271), in particular the 'what', that defines the appearance and features of both the homes and their surroundings rather than the 'how' that is concerned with the processes by which this is achieved. Although this does not appear to be well addressed in the construction regulation literature, it is a key concern of housing design projects, which are forced to respond to a double set of regulations on planning and on building (Banfill and Peacock 2007). Such projects exist in a complex world where there is a difference between 'what is required by law and the real conditions of compliance' (Kemp et al. 2000). The dividing line between these can often be negotiated with the agency that implements the regulation. It has to be done within the agency's "regulatory style", which may be, for example, confrontational or collaborative. Negotiation around innovation to meet regulatory requirements (as noted by Winch 1998) is an important element in the way house builders respond to regulation with innovative solutions.

To summarise, the focus of policy tends to be on outcomes, not processes. However, to understand how effective such policies might be, it is necessary to understand how policy impacts these processes and practices. Generally, focus has been on firms rather than on projects, mainly because both economic theory and policymaking locate innovation, and the value of innovation in the commercial context of firms. A great deal of construction research continues to view innovation as primarily associated with firms' products, rather than as a process within a broader system. (See also the related discussion in chapter 4.) The research in this chapter therefore focuses on the innovation processes and practices that regulation induces.

Case Study Example

Only selected results from one of the aforementioned case studies are presented here to illustrate how regulation and innovation play out in the context of new build housing. Before considering the case study, we reflect that in the majority of cases, the builders already used a standard approach of improved building fabric plus Photo Voltaic MGT as their strategy for compliance with regulation and planning. Associated research (Lees and Sexton 2013) has shown that house builders are selecting a narrow range of technologies in comparison to the 11 alternatives shown in Table 6.1. Choices are made to minimise the disruption to their standard design and production templates. Innovation is induced by regulations, but actors make sure not to do more than necessary. This is an example of what was mentioned in chapter 1 that minimum requirements are taken to be templates for "best practice". The result is that MGT choices are made to minimize the efforts and costs related to comply with regulation. This outcome may not be optimal from an environmental innovation policy perspective.

The case we have selected to use as an illustration concerns a small development in a conservation area of 26 homes – a mix of houses and apartments built to CfSH Level 4 as stipulated by local planning regulations. In addition, two listed buildings (a church and a barn) are on the perimeter of the development. Conservation areas are designated for their special architectural and historic interest, and developments within them are governed by strict local government and planning authority rules. Consequently, the local planning authority specified a number of additional planning requirements, in particular, that the rooflines of the development had to be consistent with the neighbouring buildings. The implications of this planning requirement for the selection of the MGT solution were profound and systemic. The house builders' default MGT solution across its UK developments was either photovoltaic or solar thermal, technologies that, as mentioned earlier, were relatively easily incorporated and embedded into their standard design and production practices. Furthermore, to support its default solution, the house builder had well-established supply chains for the sourcing and installation of these technologies. However, the roofline planning requirement dictated that the house builder's standard MGT solutions could not be used. The only MGT solution that the planners would allow were air source heat pumps, and their use was a significant departure from the house builder's established practices and supply chains. Although the decision to use MGT technology was a direct result of the need to comply with technical regulation in the form of the CfSH, the particular technology adopted was selected for externally defined aesthetic and planning reasons rather than for any aspects of its technical performance. Thus, change did not occur through technical development and appraisal from within the delivery team; rather, it was induced by an outside agent seeking to achieve something different altogether – the preservation of the conservation area's standard roofline.

Thus far, the role of the householder in the selection and use of the MGT in question has not been considered. In fact, in terms of the selection of the MGT, the eventual occupiers of the houses generally have no role to play. This is in contrast to broad trends in which end users become more important as sources and drivers of innovation (von Hippel 2009), and also compares unfavourably with fact that many innovations fail because of lack of user involvement during development (Douthwaite et al. 2001). See also the discussion of the role of users in chapter 9).

As for the eventual use and the possible technical success of MGT, the home occupiers in the case project played an unanticipated role in reconfiguring the air source heat pumps in ways that reduced their performance. Air source heat pumps require adequate space around them to function properly; a surrounding grille was installed around them to ensure that the air flow into the pump was stable. This is a technical issue that was not made clear to the homeowners and they, on occasion, changed the use of the grilles in a fashion that reduced the air pump's performance. One homeowner, for example, removed the grille to widen the garden path to allow a lawn mower to be moved between the front and back gardens. In another home, the occupiers used the grille as a climbing frame for ivy!

These two examples, though apparently trivial, illustrate that detachment between the building designers and the end users can erode the effectiveness of the associated policy aims. Reflecting the challenges related to multi-parametric optimization discussed in chapter 2, provision of space for the movement of equipment between the front and back gardens had not been properly considered. Similarly, homeowners growing ivy in the grill would greatly impair performance. Heat pumps need to be finely tuned to the requirements of the building to work efficiently and lose efficiency quickly under non-optimal conditions. This is obvious to the technicians installing the equipment, but in this case, as in innumerable other cases in building, optimization of a single system within the complex, dynamic system of a built object does not warrant a well-functioning whole. And although all requirements of regulation and legislation would be met by the installation of the heat pumps, the intention of the regulation to reduce carbon emissions would be confounded.

In the context of regulation-triggered innovation, our simple case illustrates that it is not sufficient to assess policy outcomes by counting the specific adoption of a product or a technology in the context of a project. Even though a technology is used, and even though each of the project stakeholders may have a reason to be satisfied, the policy objectives may not have been achieved in an adequate way. An innovative product has been installed. The planner has maintained the skyline of the village whilst meeting environmental regulation requirements. The homeowner is content because she or he has a house fitted with energy-saving technology. And the requirements of the regulations have been met. Still, actual carbon emission reductions are limited, and the homeowner will not have the energy cost reductions that were anticipated. The builders have had their standard systems disrupted to accommodate innovation, and ultimately, whilst all parties have satisfied regulatory requirements, only the planner may have achieved its aims.

Conclusions

The role of regulation in stimulating innovation is contested. This chapter has sought to throw light on this through a more detailed understanding of the overall processes of regulation-induced innovation. Although the policy aim of the CfSH is largely concerned with reduction of carbon emissions from new build housing, the single case study related here reveals that MGT technologies are not generally selected on their technical merit regarding the ultimate policy objectives, but rather for their cost effectiveness in effecting compliance to rules and regulations.

To understand the actual effects of policy instruments on innovation, it is necessary to understand the complex series of interactions playing out within the house building project. In practice, regulation does trigger innovation in the sense that new products are adopted and new ideas are implemented in practice. However, as the case MGT selection illustrates, innovation is a complex process involving different actors and with uncertain outcomes. It is important to look further than to the simple fact that all regulations and planning rules have been complied with in formal terms. In reality, only the local planning laws in relation to the roofline have been fully met. Beyond that, although regulatory compliance has been achieved, the intent that underpins the regulation has only been partially satisfied. Although MGT technology has been adopted, the carbon reductions will be limited because the end user has interfered with the heat pump grille. In this particular case, therefore, the innovation introduced as a means of complying with regulation will not fully satisfy the needs of the policymakers (carbon reduction), the home builder (disrupted standard practices that are unlikely to be used elsewhere) or the end user (limited reductions in energy bills). Therefore, whereas rules and norms play a very important role, their effects are not always obvious and not always as anticipated.

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7

An Industrial Network Perspective on Innovation in Construction

Lena E. Bygballe, Håkan Håkansson and Malena Ingemansson

Introduction

The construction industry involves many actors that act and interact at multiple levels, and construction has therefore been regarded as an 'archetypal network' (Miozzo and Dewick 2002, p. 46). Construction projects comprise complex external interaction patterns because they engage a set of specialist companies with different economic logics (Bygballe, Håkansson and Jahre 2013). Thus, innovation in construction is not merely a company concern; it is heavily influenced by its interorganisational nature in which innovations engage with and need to be negotiated with multiple actors involved in the various projects (Winch 1998). As pointed out in the introduction to the present volume, a common image of the construction industry is that it is lagging behind others in terms of productivity and innovation (e.g. Egan 1998). One explanation identified in previous research for why this is so is the way the construction parties interact (i.e. the nature of the business relationships in the industry [Dubois and Gadde 2002; Holmen et al. 2005]). However, practitioners have reported that they do not recognise these negative characteristics: There are many changes in the way projects are delivered, both in regard to the interaction among the involved parties and the technologies applied.

This suggests that there are conflicting views as to the degree to which the construction industry actually engages in innovation. In turn, this opens a discussion of, first, how innovation might be defined in this industry – what is being renewed and how – and second, how the innovation process relates to business relationships (i.e. how the different industry counterparts interact within and across projects and how this affects the achievement of innovation). We investigate two principal issues by drawing on insights from a

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theoretical perspective that represents more than forty years of empirical studies of technology development and innovation: the industrial network perspective (see Håkansson et al. 2009). In this perspective, innovation is considered a network phenomenon in which the creation and actual use of new combinations of actors, activities and resources must be understood in terms of interorganisational interaction processes (Håkansson and Waluszewski 2007). In construction, this occurs both within the project (temporary network) and across projects (the permanent network) (Dubois and Gadde 2000, 2002). We identify three key aspects that follow from an industrial network perspective and use them to examine various examples of innovation in construction from an ongoing research program on innovation in the Swedish and Norwegian construction industry.

Innovation in the Construction Industry

Conventional wisdom claims that the construction industry is lagging behind other industries in regard to performance indicators concerning productivity and innovation (Egan 1998). In several countries, the construction industry scores low on R&D expenditure and few construction firms take advantage of R&D or innovation programmes offered by governments (Seaden and Manseau 2001; Miozzo and Dewick 2002).[1] However, the literature recognises that these indicators of innovation are not necessarily applicable to this particular setting, or any other, for that matter. As an example, Winch (2003) showed how the standard industrial classifications categorise the most innovative parts of construction (i.e. design and product development) as Other Business Services, not as construction. Seaden and Manseau (2001) argue that innovation in organisational processes is overlooked, which means that renewal in core activities of construction, such as in delivery methods and contracting arrangements, is not really considered or paid attention. This suggests that one part of identifying innovation in construction, as well as how innovation processes can be facilitated, is related to applying an appropriate definition or view of innovation. Slaughter (2000, p. 1466) formulated innovation as ‘a non-trivial improvement in a product, process, or system that is actually used and which is novel to the company developing it’. More recent research uses a similar definition, and argues for the need to include the application element of innovation (Gambatese and Hallowell, 2011). We concur with these views since they accentuate the need for considering the role of interaction.

Challenges in relation to innovation are often attributed to the complex interaction patterns in the internal network of the companies and the external network, both within and across projects. Internally, the project-based nature implies a short-term focus, and it has proved difficult to learn across

[1] R&D expenditures range between 0.01–0.4% of construction value added for countries in the Organisation for Economic Co-operation and Development (OECD) (statistically limited to contractors and subtrades) compared to 3–4% in manufacturing or 2–3% for all industries (Seaden & Manseau, 2001).

projects and to benefit from gains achieved in one project to the next. Participants are assigned to other projects as soon as they finish one. Faced with different objectives and a new team, it becomes difficult to recognise the usefulness of the experiences made in the former project (Grabher 2002). For innovation to happen, construction firms must be able to adopt and implement new ideas on projects or to transfer results from one problem-solving experience to the firm level (Winch 1998). However, as Bresnen et al. (2005) remarked, transferring knowledge generated in one project to the wider organisation is difficult because of existing routines and knowledge and power structures. New knowledge may threaten existing practices and, as such, be counteracted. Also, whereas the learning level is high *within* the separate projects (because of knowledge barriers needing to be crossed when different actors face a common task), this learning becomes very specific to the particular task and team and therefore is difficult to transfer to other projects and to the wider organisation (Hobday 2000; Principe and Tell 2001; Scarbrough et al. 2004). Furthermore, the interorganisational nature of construction is challenging. Even if projects are by definition learning arenas, innovation may be hampered by the different views and motives of the involved parties (Slaughter 2000) as well as the distribution of power amongst them (Harty 2005). Transferring new solutions from one project to another may be difficult because of the creation of new constellations as the result of the traditional focus on price: the lowest bid wins (Dubois and Gadde 2000). The interorganisational nature of construction thus adds to the complexity of innovation. This was discussed in Chapter 6, where focus was on regulation induced innovation. But complicated project set-ups adds to the complexity of innovation also in other situations, where regulation is not the key trigger. A first step towards understanding innovation, therefore, is to delve into the specific features of interaction across firm boundaries.

An Industrial Network Perspective on Innovation

The industrial network perspective sees companies as embedded in a network of different actors with which they interact to gain access to resources and activities that they themselves do not possess (Håkansson and Snehota 1995). This perspective can be seen as responding in a comprehensive way to the call of many authors in the present volume to conceive of construction stakeholders broadly and to consider the interaction of stakeholders in innovation. The interaction processes create actor bonds, resource ties, and activity links, which influence not only the individual party in a relationship and the relationship itself but also the network of other companies to which the parties are connected. Actor bonds are mainly social and organisational phenomena, whereas resource ties can be both physical (products and facilities) and/or organisational entities (business units and business relationships). Activity links comprise different logistical or production activities taking place across organisational borders (Håkansson and Waluszewski 2002). Through this perspective, innovation can be understood and studied as changes in bonds, ties and links, or as new combinations of such (Håkansson and Ingemansson 2013).

New ideas often emerge at the intersection between different bodies of knowledge as they are confronted or need to be combined in a certain way (Håkansson 1987). In an exchange situation, a producer has a certain type of knowledge concerning the product or technology whereas the user has specific needs, which can be combined into new innovative solutions. How this exchange takes place and what level of knowledge or learning that can be achieved greatly depends on what type of interaction exists among the counterparts, or as put by Håkansson and Ingemansson (2011, p. 68): 'the features of interaction determine what kind of knowledge can be transferred and created'. Thus, there are different types of exchange situation/interaction that can result in different levels of learning. The 'simplest' form of interaction is through the exchange of a product in which no more interaction takes place than the buying/selling process itself; no changes are made to the product and the user/buyer learns by using the product in its own operations (without making any joint adaptations). The only thing that the producer/seller learns in this situation is the price at which the product was sold and in which volumes it is being consumed. At the other end of the interaction spectrum is the process through which (at least) two counterparts jointly challenge existing knowledge in terms of trying to solve a specific problem that requires knowledge creation. This will change not only what they know separately but also what they know and can achieve jointly (Bygballe 2006; Håkansson and Waluszewski 2007; Håkansson and Ingemansson 2011).

For knowledge and new technical solutions to become innovations they need to become related and adjusted to existing products, systems and organisational solutions, which go beyond the dyadic relationship. Previous combinations and interconnected investments result in a network of interdependent solutions, which makes them difficult to replace or combine with any solution that has been developed outside this network (Håkansson 1987; Gadde and Håkansson 2001). Stinchcombe (1990) argued that the adjustments needed to implement a new solution that differs significantly from existing supporting solutions involve great costs. Therefore, achieving innovation is a matter of creating benefits for different actors in terms of creating a match with their respective resource combinations and ongoing activities. This might induce significant costs if it breaks considerably with the investments in place (Håkansson and Waluszewski 2007). It makes learning and innovation the result of a collective process with several actors interacting over time. Specific technologies evolve towards a joint standard from the repeated and joint investments over time. Or, as Håkansson and Waluszewski (2002, pp. 47–48) put it:

> 'In almost every industrial structure there are basic technologies, which, due to many and related investments carried out over a long time, are very costly to change towards new directions.... Since it is constructed and used by actors, it is continuously exposed to interaction processes, so it will always be exposed to new ideas. However,

> due to its heaviness, all changes have to be carried out in restricted steps, in certain stable directions building on the existing solutions.'

Just as the driving forces of innovation are the outcome of interaction processes, so are the hurdles. Whereas the network is an enabler of change through the variation of actors and resources, it represents the already implemented solutions and investments by creating a 'heaviness' in the system and a path dependency restricted to certain technologies that can be difficult and costly to deviate from. The interdependencies between actors and resources in an industrial network thus work both as enablers and impediments to change and innovation, which is one of the paradoxes of the network (Håkansson and Ford 2002).

Considering the actual use of a new solution as an essential part of the innovation process contradicts other influential views on the relationship between exchange and innovation. For example, models conceptualizing the business landscape as a market will argue that either suppliers or users instigate innovation with price and demand as the driving forces of renewal. (See, for example, Solow 1956; Mankiw 1998.) In this perspective, innovation is seen as a linear procedure of new solutions being 'pushed out' by technology providers or 'pulled out' by users with specific demands. As Snehota (2004, p. 16) argued, this neoclassical market model still dominates much economic thinking:

> 'The neoclassical conception of market as the price determination mechanism is attractive. It has support of much of the theorizing in economics, is parsimonious and coherent and has gained a special status as the dominant perspective. The problem is that the neoclassical perspective on the market often provides only limited guidance for how to act within a market.'

Nevertheless, empirically based research provides strong support for the belief that new solutions need to fit within both a using and a producing environment in order to become innovations. Firstly, research indicates that a large number of product development projects fail because the resulting product does not sell as well as anticipated. This means that potential customers have been unable to use the new product (see, for example, Cooper 1979; Dougherty 1992; Pavitt 1991). Secondly, when successful innovation does occur, which means that the new product has become a widely used solution, it often takes place in established producer-user relationships (Harrison and Waluszewski 2008; Håkansson et al. 2009).

Understanding Innovation as Resource Interaction Processes

The essence of the industrial network understanding of the business landscape is that business relationships systematically relate different internal aspects of the company to specific counterparts and thereby become a part of the larger network, relating to third parties (Håkansson et al.

2009; Håkansson and Ingemansson 2013). Thus, the material and immaterial resources used are part both of the single company and of its environment. This fundamental aspect of the economic activities of companies is of course consistent with Schumpeter's view of innovation as 'new combinations' (chapter 1). But the fact that firms are interdependent in terms of the resources they employ also has consequences for how we may understand how these resources are changed and developed over time and how innovation happens: namely, as a result of *collective* adaptations, change and learning. This in an important and consequential way moves beyond Schumpeter's early theory of economic development and entrepreneurship. How, then, can we study these interaction processes between and among companies and their resources? How do we capture what is happening between the interacting parties and the resources that they depend on and the economic effects of these resources being changed in any way?

One way to identify where change can appear and the effects it may result in is to use the 4R model (four resources) developed for studies of innovations in business networks (Håkansson and Waluszewski 2002). By the use of this theoretical model, it is possible to identify a large number of resource interfaces that can be changed and where variations that are affecting the total construction process can appear. It allows for the study of the resources, both physical and organisational, assumed as being involved in the interaction processes of different actors relating and adapting to each other (Håkansson and Waluszewski 2002; Baraldi 2003). In this model, the resources represented by any particular company are divided into four resource categories; two are mainly physical (for a detailed, discussion see Håkansson and Waluszewski 2002):

a. the *products* of any particular organisation as the result of producer-user interaction
b. the *facilities* or equipment used to produce and deliver these products, often in combination with other facilities in an effort to cut costs

The other two are mainly organisational:

c. *organisational units* that represent the people involved in the company or organisation in terms of their knowledge, working routines, and their ability to cooperate with other organisations
d. *organisational relationships* between any other companies or organisations that can be used to create more efficient resource combinations or activity links over time.

By identifying and analysing these resources and the way they interact, we can distinguish technical interfaces in which different technical resources are combined in different ways from organisational interfaces in which organisational units and business relationships are combined. There are also mixed relationships when technical and organisational resources are combined (Håkansson and Waluszewski 2002). Technical and organisational changes are thus often interlinked, and the 4R model can be used as a tool to both identify and analyse such interdependent development processes over time. In this way, new resources and changes in their use and in new combinations of resources can be identified and the potential consequences of the changes evaluated. Barriers to change can be found in the way resources have been adapted to each other over time.

In sum, using the industrial network perspective to understand innovation in construction implies paying attention to three specific aspects. The first is how individual companies relate to other companies in terms of type of relationships/interfaces with suppliers, customers and competitors (Håkansson and Johanson 1992). The second, which is subordinate to the first in terms of being a consequence of the types of relationship that exist, is how collective learning and knowledge transfer takes place (or not) across firm boundaries (Håkansson and Waluszewski 2007). The third aspect is how changes in different types of resources interrelate and create direct and indirect effects across the network, such as the interlinkages between technical/physical and organisational resources (Håkansson and Waluszewski 2002), which in turn will affect the extent to which the new solution is actually used and becomes embedded.

Empirical Examples

In a study of learning and innovation in the construction industry encompassing both Norway and Sweden, we used surveys, conducted interviews with chief executive officers (CEOs) and case studies in both countries to collect data (Bygballe and Ingemansson 2014, 2011; Håkansson and Ingemansson 2013, 2011). The objective was to investigate what type of innovation that construction companies generally engage in (i.e. technical and/or organisational), how it takes place (i.e. in terms of types of learning opportunities or ways of working/organizing) and what the most important counterparts are (i.e. types of interorganisational interfaces). From this study, we have presented a few empirical examples to illustrate the implications of an industrial network perspective for our understanding of innovation in construction, focussing on the three aspects of this perspective presented here.

Starting with the most basic assumption of the industrial network perspective – namely, that the character of any individual company is determined by the network of other companies with which it interrelates through particular resources and activities – our study confirms many earlier studies investigating how construction companies value and utilise their supply network. Whereas customers are considered the main drivers of innovation, suppliers are valued less in such efforts (e.g. Dubois and Gadde 2002; Akintoye et al. 2000). Because subcontractors and suppliers often comprise 60–80% of the total costs of a construction company's project – meaning that these actors to a very large extent influence the main contractor's margins – there seem to be great development opportunities in this part of the network that could have a significant economic impact. That suppliers in general are not valued very highly as collaboration partners by construction companies indicates that the relationships are not very strong or long term. This appears to both create and to be an effect of a short-term focus of temporarily adapting within the individual projects. From the study, we saw that even if suppliers were considered important for innovation in the Norwegian survey (as opposed to the Swedish survey), the relationships to the supplier side were very weak. The picture that emerges is of *companies temporarily and pragmatically adapting their separate resources in each and every project without actually inducing long-term or mutual change and learning*.

Nevertheless, our CEO interviews and case studies showed positive attitudes towards, and rendered specific examples of, long-term efforts in which customers and suppliers collaborate to create new solutions. Another main result of the Swedish survey was that one of the most important types of renewal taking place during the last five years was the increase of partnering relationships with customers. In the interviews, a common perception among the Swedish and Norwegian CEOs was that the existing ways of relating in the short term and at arm's length were key barriers to innovation. One of the CEOs claimed that 'we need to find partners instead of dancing with everybody!' Long-term orientation towards the same counterpart can enable the utilisation of a new solution and thereby bring about efficiency improvements.

A case of one of the Swedish construction firms in the study illustrates the benefits that can be achieved by a more long-term orientation. In the late 1990s, the firm started a new type of production program for residential building based on standardisation in both the production process and the components used across projects in different countries. The major development relates to assembling modules in a factory and transporting them to the various project locations; it uses the same organisation across the projects and thus consists of the same construction parties for all the projects. In this way, the project organisation, which consisted of the same actors and people, learned across the projects and could continuously improve the production process and the final construction. The firm is combining its internal and the external network across projects over time in order to exploit previous learning and make the production process more efficient through the standardised resources. More than a decade later, firm representatives report that they see effects in terms of the new production process becoming more efficient and that it is considered a very successful investment.

In a different case, a technical contractor developed a new energy-effective ventilation system through close collaboration with different producers of the various system components. Over several years, the system has been adjusted and tested to meet ever increasing customer demands in relation to indoor climate and energy consumption. It has developed from being a 'simple' system for ventilation to becoming the 'building's technical highway', incorporating different technical solutions related not only to ventilation but also to electronics, telecommunication, fire extinguishing, and vacuum cleaning. It is clearly recognised that the knowledge about the combination of product and user experiences that have been shared and discussed between the company and the suppliers has been a prerequisite for developing this new product.

Another example illustrates in a similar way how resources are combined to create efficiencies and effectiveness: One of the largest housing contractors in Sweden discovered that there were fourteen distinct and different ways of assembling a wall throughout the organisation. Based on an evaluation of what was going on, the firm decided which method was the best and chose it as a standard method across projects. The company chose to use a single supplier that had specialised in this solution instead of using a wide range of suppliers. In addition, the company chose to work with just one type of a particular special-purpose door that would fit the assembly method and, consequently, a single supplier for this product. By doing this, the two parties managed to co-develop a particular type of door that suited the standards of all the projects. In an interview, the CEO of the company acknowledged that it would take time before all employees and subcontractors fully accepted and implemented the new standardised way of working, but the key argument was that over time it would improve the efficiency of the construction process.

These examples serve to illustrate the significant effects of a long-term and collaborative relationship of contracting firms and suppliers. The examples are also closely related to the second aspect concerning collective learning and knowledge transfer. In the first example, the different units in the stable project organisation had the opportunity to learn collectively as its members work together across several projects and refine the final product and production process. The other two examples also illustrate how learning between a customer and its suppliers (as well as among suppliers in the second example) enables the development of new products and the way to use resources in the construction process. All examples show that the very practice of *jointly* developing the product and the process through which it is produced creates mutual understanding between the different units and how to jointly use their respective resources in the most efficient manner. The firms in these examples are creating a particular resource combination that is interconnected across the boundaries of the involved parties and that the process can generate benefits for these parties.

Whereas these illustrations are positive examples of how the different actors in the industry relate to one another and learn across projects, our surveys indicated that in many ways construction companies are still rather isolated types of organisations. According the surveys in both Norway and Sweden some of the most important driving forces of innovation (in addition to the customers) are the internal staff, the own personal network or that of other units within the internal organisation. The most frequently used learning sources are learning by doing or taking internal courses. Thus, whereas the internal network of the company is highly valued in terms of learning and inducing change, the external network and supplier relationships seem to be underexploited resources.

Finally, the examples illustrate the third aspect about mixed interfaces. Enabled by relationships with specific partners, the different units develop, use and adapt the physical resources over time. This aspect was also particularly well illustrated in the CEO interviews when they were asked about examples of innovations; several mentioned the use of building information modelling (BIM) as a typical example. They recognised that the technical aspects of this new technology were clearly important, but just as important were the knowledge required to utilise this new resource and user experiences. One of the CEOs acknowledged that his firm had underestimated what it actually takes to make the whole organisation implement BIM when deciding that it should be used in all projects: 'To ensure that project managers apply BIM, we need to make it as painless as possible. The greatest barrier is existing ways of working, so they need support. We often neglect the "software", that is to say, the organisational and practical barriers'. It was also acknowledged that this related not only to the internal organisation but also to external parties participating in the BIM projects. Thus, similar to the example of the standardised assembly solution, the BIM example shows that because new solutions often require replacing existing ones and because of the solutions' indirect effects, embedding any new or changed resource or combination of different resources will take time.

Conclusions

In this chapter, we have examined the implications of an industrial network perspective concerning our understanding of innovation in construction. We have used examples from an ongoing study on innovation and renewal in the Swedish and Norwegian construction industries to illustrate some key implications of this perspective[2]. For example, the network is essential, and the way that actors relate to one another and the type of their interaction are of utmost importance for the innovation outcomes. Within this, suppliers are important, both because of the knowledge and experiences they may provide into process and product development, and because suppliers are highly involved in a firm's value creation activities. In construction, subcontractors and suppliers often account for 60–80% of the total costs of a project, indicating the importance of the supplier network for construction companies. Consistent with previous studies (such as Dubois and Gadde 2000), results from our study show that a relationship with suppliers often is an unexploited resource. The ability to create the type of interaction needed to achieve innovation seems to be absent. Benefits can be created by a more long-term and partnering orientation towards suppliers. Knowledge sharing enabled by closer interaction between parties has consequences beyond the dyadic relationship between a customer and a supplier; it also can be useful in other relationships. Exchange of product and process knowledge in combination with user experience enables adaptations, improvements and development of new solutions. A final aspect concerns the acknowledgement that innovations often involve the combination of physical/technical and organisational resources. For example, implementing BIM in a project organisation will require substantial changes in knowledge about use of BIM technology, and changes in existing ways of working.

[2] Also see Bygballe and Ingemansson (2011), Håkansson & Ingemansson (2011, 2013), and Bygballe and Ingemansson (2014).

These changes will have to cut across firm boundaries. This illustrates that the extent of earlier investments may determine the extent of innovations.

Innovation engages and needs to be negotiated with multiple actors involved both in the various projects (Winch 1998) and across both temporary and more permanent networks (Dubois and Gadde 2000). Our theoretical perspective is important because it can help to capture the complex interaction patterns embedded in the construction network. With the network perspective, we have established a strong reason for discussing innovation in construction, and have shown how we might understand the way that the innovation processes unfolds in this setting. Applying the insights from the industrial network perspective provides opportunities to identify and analyse the complexity of the construction network. Given this complexity and the interdependencies that exist, any long-term changes in resources and resource combinations are likely to have effects far beyond the original association. New solutions invented in one project (a temporary network) are difficult to transfer to other projects when the constellations are ever changing.

The network perspective on innovation is potentially useful for practitioners in enhancing their understanding of what it takes to innovate. Considering the implementation of new technologies (such as BIM; new ways of working, for example, lean construction; and new delivery forms, partnering, etc.) in terms of changes in the use and combination of different types of resources directs the attention towards both opportunities and potential barriers, and increases understanding of how innovations are different, what the innovation process is like, and what are important drivers of and barriers to innovation in construction.

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8

Innovation Diffusion Across Firms

Graeme D. Larsen

Introduction

This chapter seeks to add to the study of innovation diffusion as enacted within the UK construction sector. Whereas using relevant theoretical frames as touch points, the chapter maps out challenges associated with understanding innovation diffusion within the UK construction sector. Central to the argument developed here is just how diverse the UK construction sector is, resulting in the need to focus upon a specific constituent perspective within the sector. It is argued that constituents of the UK construction sector experience the reality of innovation diffusion differently. The chosen focus here is medium-size and typically regionally based construction firms rather than the *big guns,* because statistics continually demonstrate that this group of smaller firms undertake more than 80% of the sector's output. As is pointed out in other chapters in the present volume, and as argued theoretically in the industrial network perspective of chapter 7, firms do not innovate in a vacuum. Innovation and diffusion occur within networks of firms typically around a project. A framework drawing upon empirical data is provided to offer additional insight on the process and the interconnections. It is argued here that the unit of analysis or level of understanding termed the *firm* can actually be fairly unhelpful for understanding innovation and its manifestation and diffusion within the broader UK construction sector, because this occurs across networks of firms.

Antecedents

Businesses within the UK are continually encouraged to be innovative and adopt innovations in order to improve their competitiveness. Innovation within the majority of industry reports is seen as some kind of panacea, and

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in academic publications is typically described as a positive although problematic thing. (See the related discussion in chapter 2.) Innovations (within the construction sector) range from small advances in construction methods, materials, and technologies to radical procurement routes. All of these innovations result in a change or adaption to the manner in which professionals and operatives undertake their work; thus, tangible innovations come as a package deal typically requiring changes in an actor's behaviour. Readers should be mindful of the suitability of the innovations for the UK construction sector. Thus, caution is required to ensure that innovation occurs for the right reasons and within the right areas where there is the most room for improvement and benefit across the sector to meet current challenges (e.g. energy and sustainability). This caution is needed to ensure that the sector is not simply trying to adopt the latest innovative fashion. Thinking in such strategic terms does not always fit well with the UK construction sector; as it often relies on being highly agile and responsive. The term *UK construction sector* does not help, because it has become almost meaningless, including everything and nothing, from architect, housing surveyors, painters and lighting manufacturers. At this stage, it would be remiss not to mention the countless innovations the UK construction sector has been encouraged to adopt from other industries, only to realise that they did not fit the structure, operational routines or particular constituents of the sector (Green et al., 2005).

Central Themes

It is a core message in this volume that innovation can be viewed in many different ways. In this chapter, innovation is understood not to be fixed, but to be readily occurring during the diffusion process. As practitioners and firms interact with a new material, process or tool, they make changes and adjustments to it so that it fits their unique needs. Of course, no novelty is claimed in this; many have already championed the need for such a stance (Fleck 1993). It is not possible to write about innovation diffusion across firms without acknowledging the very first stage, the notion of awareness and the role it plays in the process. The ability to become aware of an innovation in the first instance is unique at all levels: actor, project, department, firm, networks of firms and sectorial. This unique capability can be a defining factor, yet it has only recently begun gaining acceptance in the construction management field (Larsen 2011; Sweet 2013). This is because levels of awareness vary widely across the sector, even within the same firm, department or project. Thus, understanding awareness, who has it and which firms have it in the network of firms you are embedded in is an important consideration.

The fact that the majority of construction work undertaken is by regional small- and medium-size firms seems often to be underplayed within innovation diffusion studies. The voice of such firms is also often unheard in both research and industry best practice initiatives. Research into how firms of such a size operate and engage in the innovation diffusion process is limited, but with a few exceptions (e. g. Sexton and Barrett 2003; Green, Larsen and Kao 2008). Research associated with the UK construction sector typically distinguishes among industry, firm, project and actor levels. However, an even finer grained analysis is required to get the very heart of the issue. To simply state that this is a 'firm' level understanding is not enough; firms do what they do as part of a network with other firms, and the innovation diffusion process occurs within this network. Firms cannot operate in isolation of other firms (Kao et al. 2009; see also chapter 7 in the present volume), resulting in innovation and diffusion occurring across networks of firms. This view helps us move beyond the notion of a single firm as a unit of analysis for understanding innovation diffusion within the UK construction sector. In addressing this, insights are offered into the importance of unique networks within given contextual settings while influenced and influencing the broader institutional and structural forces.

Points of Departure

The constituents that make up the UK 'construction sector' are very different; thus, an understanding that suits the whole 'construction sector' is problematic at best. As the reader, ask yourself what a jobbing builder, a manufacturer of boilers, a building surveyor and a high-profile architect have in common. The answer proposed here, is, very little indeed, yet many would say they are all 'in the construction sector' and can be described in the same manner despite the fact that the reality of their business and the nature of their work are very different. For this chapter, the chosen constituent of the UK construction sector is regionally based contracting firms.

With the focus being these regionally based firms, it is acknowledged that firms operate not in isolation but as a network based around either geographical area, market sector and, indeed, particular projects (Kao et al. 2009). These networks of firms and their importance to innovation diffusion are typically oversimplified with attention often focused solely upon one firm rather than networks of firms. Because innovation often actually occurs during the diffusion process, a number of firms will be involved.

Finally, the unit of analysis referred to as the *firm* typically oversimplifies the fragmented nature of departments, different offices, subsidiary firms and stakeholder firms, meaning that even one firm does not have a unitary voice associated with innovation diffusion. Construction firms tend to be rather *messy* organizations, most often emerging organically rather than strategically.

How to Approach the Problem

With some of the complexity of the subject and context described, it is important to consider the theoretical and methodological challenges these raise. The innovation diffusion literature is theoretically fragmented, and there is *no one best approach* for understanding it. However, it is important that we put our flag in the sand and view the subject from a chosen position. The agency-structure perspective, championed by some leading social scientists (e. g. Archer 1988; Giddens 1979; Ritzer 1996), is used as a key touch point. Giddens's structuration theory may be familiar to some readers because it has been used within the construction management to understand such things as supply chain management (Fernie 2005). However, numerous theories could be described as falling within the agency-structure perspective, and it is not the author's intention to debate their strengths and weakness. The central alignment with the agency-structure perspective relates to how it views individuals, their contextual setting and broader institutional or structural forces (Currie and Suhomlinova 2006).

Other perspectives privilege individuals with structural forces being subservient or, on the other hand, privilege structural forces and view individuals as subservient and with limited choice. The agency-structure perspective offers a realistic alternative to that dichotomy because it advocates that individuals (actors) are shaped and influenced by their contextual setting and the broader institutional forces, yet importantly at the same time, individuals shape and influence their contextual settings and broader institutional forces (Pettigrew 1997). Thus, both actor and structure are not only privileged, but actually essential for any understanding offered. Adopting such a perspective can result in a complex and multi-layered view of innovation diffusion because it is mutually constituted. The perspective thus needs to be aligned with an understanding of the interplay between the various themes discussed, how they impact actors, the contexts and how these shape and are shaped by broader institutional and structural forces.

Certainly, individuals experience innovation diffusion very differently, but never in a vacuum. This means that actors have chance exposure to innovations and are influenced by highly structured and powerful marketing campaigns and the persuasive powers of key people within an their communication network. Certain actors may be in a position to allow high levels of awareness to innovations, while others find themselves under-exposed to innovations. This directly affects an actor's opportunity even to enter the innovation diffusion process. Consideration of the explanations above make it increasingly clear that actors actually have less control than some might suggest (Rogers 2003). Yet, it is also clear that actors are not passive or subservient to institutional or structural forces as others allude to (Burt 1982; Valente 1995). Both play a role.

The themes of awareness, influence, negotiation and communication networks associated with innovation, while intangible, are very real. Fleetwood (2005) claims such themes as real because they have the ability to produce effects and change. This is certainly true of awareness, influence and negotiation because they will affect the innovation diffusion process. Communication networks can be seen as providing the temporal space where innovation diffusion is socially negotiated by actors. This is where innovations are ascribed meaning and value, and are even modified to suit particular contexts where diffusion is enacted.

The arguments mobilised thus far enable us to appreciate the role of actors, their contexts, and broader institutional forces by which they are interconnected with actors shaping, yet being shaped by their surroundings (Pettigrew 1997). Actors are part of a dynamic network through which innovation diffusion is shaped, changed and contested over time but, of course, not in isolation of the immediate surroundings or broader institutional forces. Aldrich and Zimmer (1986) argue that communication networks and thus the relational ties that form them provide a key unit of understanding how innovation diffuses.

Mapping Networks of Innovation Diffusion

One method for mapping what innovation diffusion looks like is social network analysis (SNA). This branch of sociometry *claims* to reveal unseen structures that shape networks through the position of actors within them: alliances, subgroups, beliefs and personal agendas (Moreno 1951). The historical development, methods and application of SNA are well documented (e. g. Scott 2000; Wasserman and Faust 1994) together with the complementary relationship with innovation diffusion (Burt 1982; Valente 1995; Larsen 2005, 2011).

It is acknowledged that SNA is still evolving as demonstrated by the different ways it is used. For example, although SNA is embedded in the positivist perspective, a number of authors are now using it in a descriptive rather than prescriptive fashion (Peay 1980; Lievrouw et al. 1987; Bidart and Lavenu 2005; Agneessens et al. 2006; Larsen 2011). Coviello (2005) outlines a 'bifocal' approach using SNA and content analysis while acknowledging the challenges of managing the dynamic nature of the network. In the present chapter, in line with the theoretical stance outlined in the previous section, a less deterministic position is adopted acknowledging and equalling privileging actors and structure.

SNA already has a number of proponents in the construction management academic community and has been used in a variety of ways. Loosemore (1998) used SNA to complement qualitative techniques in order to offer a better understanding of crisis management efficiency. Swan et al. (2001) and Larsen (2003, 2005, 2011) experimented with the technique in order to understand the shape of trust networks and innovation diffusion, respectively. However, regarding the UK construction sector, perhaps the ongoing work of Pryke and his commitment to the SNA method to address a range of issues is of most interest to readers seeking further understanding (Pryke 2012).

Attributes Shaping Informal Networks

Innovation diffusion literature highlights factors that shape innovation diffusion informally. Katz's (1955, 1957) seminal work offers a pluralistic perspective linking innovation diffusion and informal communication networks. Central to Katz's work is the notion (also espoused in chapter 2 in the present volume) that innovations are drenched with risk and uncertainty, meaning that actors *retreat* to their informal networks of friendship, trust, advice and socialization when engaging with diffusion (Tichy et al. 1979). Actors seek out other actors who can offer high levels of trust, friendship and the other informal attributes. Literature suggests that these attributes shape the innovation diffusion process (e.g. Tichy et al; Albrecht and Ropp 1984). These attributes are the ingredients of the innovation diffusion process as an emerging network, and are of prime importance when practitioners and academics consider the actual diffusion of an innovation. The attributes have been made to shape the network for the empirical data provided in this chapter. These include whom actors went to for advice, communicated with, believed drove innovation, saw as friends or innovators, socialised with, trusted and most importantly sought opinions from (all informally, by choice, not through a structured management or organizational mandate).

Mapping a Network

A social network to represent the innovation diffusion process can be produced using a number of different software packages (e.g. UCINET or Gephi) with different options for analysing and graphically representing the network. Data for building such networks is typically gathered through surveys, although interviews and observations can also be used. Questions focus upon asking respondents about the theme's attributes above and highlighted by Tichy et al. (1979) and Albrecht and Ropp (1984). Because of the very personal nature of the questions, building trust with the respondents is vital.

Using the relational data provided, a binary matrix is constructed. The matrix is made up of two axes using the relationship attributes established within the literature and previously discussed in the early section (Tichy et al. 1979; Albrecht and Ropp 1984) and the nominations from the respondents. The matrix is populated, whereby 1 represents the existence of a relationship and 0 represents no relationship. Some seek to add a *weighting* to the relationship, perhaps 1 to 5, depending upon strength but that was not deemed suitable here. With the data inputted as a matrix, the software uses statistical calculations to construct a network (often known as a *sociogram*) based upon the data forming a closed network with no exogenous influences (this is an acknowledged weakness in the SNA method).

The data used in the innovation diffusion networks for this chapter is derived from more than 12 years of empirical research into innovation diffusion within the UK construction sector, with the majority being offered here for the first time. The circular nodes are the innovation diffusion themes discussed (advice, friendship, trust and so on), whereas the blue or black square nodes are respectively the names of the actors (blue) or firm type of profession (black) freely nominated through the empirical data collection related to those themes. For the purpose of publication, names of all actors are fictitious.

The Innovation Diffusion Network

Drawing upon empirical data, the following section depicts how one actor experiences the innovation diffusion process within the firm that employs him or her. The circular nodes are the innovation diffusion themes discussed (advice, friendship, trust and so on), whereas the blue square nodes are the names of the actors nominated. The reason for presenting this is twofold: first, to illustrate how complex the innovation diffusion network is for one staff member within a firm, and second, to help illustrate the limitations of using the firm as a unit for our understanding rather than the *network of firms* that all shape the innovation diffusion process.

This network represents the innovation diffusion themes as experienced by one actor within the firm they are employed by. It does not consider the connections outside of their firm (those are represented in Figures 8.2, 8.3, and 8.4). Thus, for Figure 8.1 the firm provides a boundary for the network. The network represents how an actor experiences innovation diffusion, an experience unique to each employee. Each firm or stakeholder associated with the project will have an individual network for each and every actor. This fact makes understanding the innovation diffusion process as a network

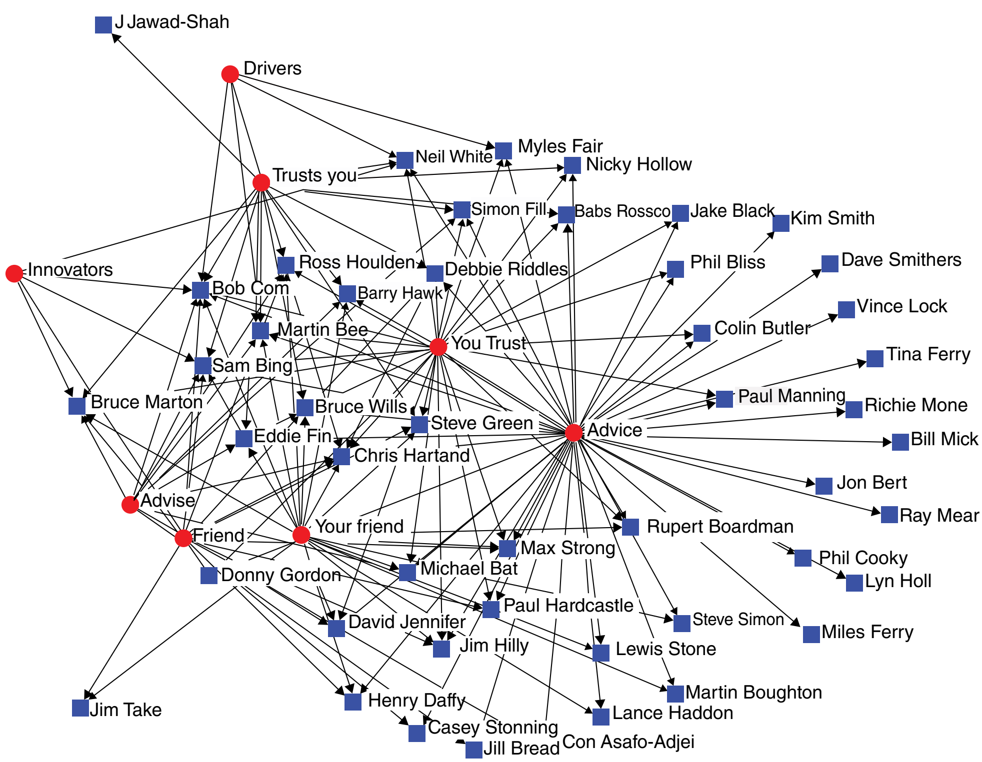

Figure 8.1 Innovation Diffusion Network for One Actor Within One Firm. (Larsen 2011)

extremely challenging as it becomes extremely complex very quickly. Whereas this network (Figure 8.1) is mapping the innovation diffusion process at the actor level bounded by the firm employing him or her, the arguments developed in the first half of the chapter championed the notion that innovation diffusion actually occurs not within one firm (and its actors), but across a network of firms. The following section presents illustrations of what these networks of firms may look like.

The Network of Firms Engaged in the Innovation Diffusion Process

The preceding section presented what the innovation diffusion network may look like for one actor within the firm he or she works for (meaning the network is 'bounded' by the firm). However, it is argued that one firm does not innovate in isolation, nor can it diffuse an innovation across a sector that is structured like the UK construction sector. Instead, innovation diffusion occurs across a network of firms. The following section thus moves beyond the single firm to networks of firms, presenting three networks at the project level (far more representative of the reality experienced by construction practitioners). Each network represents how one firm views the way it fits within the innovation diffusion network on a project (drawing upon real empirical data). The networks are context specific; thus, the type of innovation, the project and the firm all impact the network structure. No doubt each of the other firms in the network (working on the same project) would have a different opinion or perspective on their relationships with the other firms in the network. The circular nodes remain the innovation diffusion themes

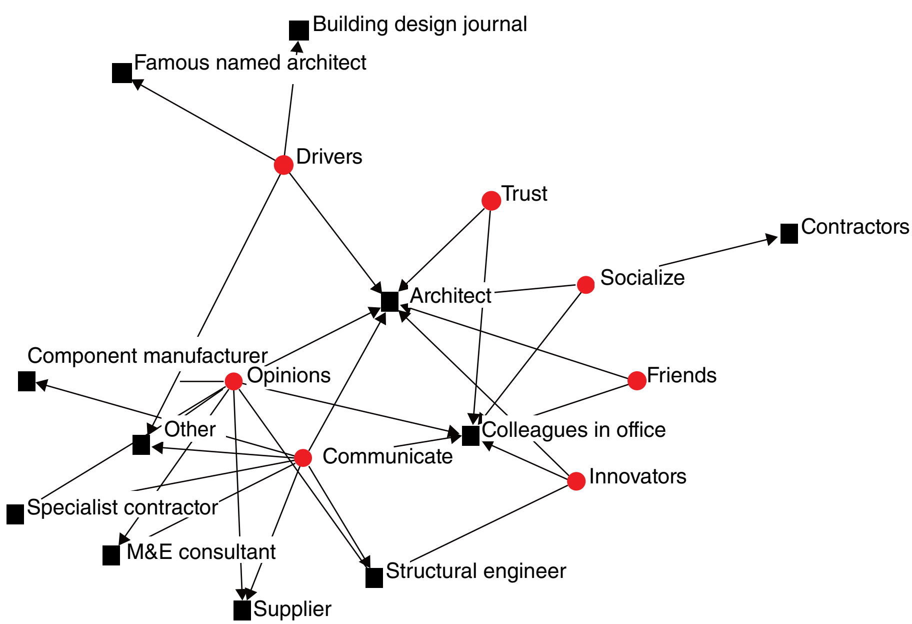

Figure 8.2 Network of Firms Enacting the Innovation Diffusion Process (not Artificially Bounded by One Firm).

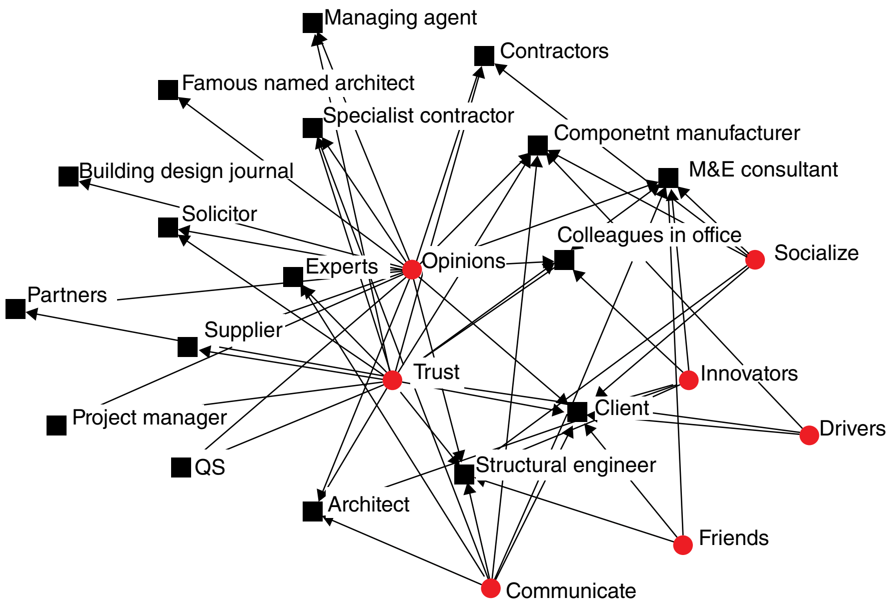

Figure 8.3 Network of Firms Enacting the Innovation Diffusion Process (not Artificially Bounded by One Firm).

discussed (advice, friendship, trust and so on), whereas the black square nodes are firm type, profession or indeed other source freely nominated.

Although limited, Figure 8.2 illustrates how the firm (recognised by the 'colleagues in office' node) represents only a very small part of what happens within the innovation diffusion process enacted regarding this construction project. All the stakeholders mentioned in the network play a role in the innovation diffusion process. Some firms or professions, such as architects, play a stronger role than others. Also important to note is that they actually play different roles, and are communicated with and perceived differently. For example, architects, colleagues in the office and structural engineers are seen as innovators, yet it is only architects and colleagues in the office who are also trusted, seen as drivers, have their opinions sought, and so on.

Figure 8.3 illustrates a more complex innovation diffusion network between firms. Like the previous network of Figure 8.2, this network presents one firm within a group of firms engaged on one particular project. The data produces what can be described as a very *outward*-looking network. Certainly colleagues in the office play a key role being innovators; however, the firm interacts with a vast amount of stakeholders (other firms) as they enact the innovation diffusion process.

The key point regarding Figure 8.3 is that there are far more connections and far stronger connections with stakeholders outside the firm than actually within it. This represents just how complex the innovation diffusion will be. These stakeholders are all part of the project, and thus influence how successfully innovation occurs and can be taken up on that project, how much negotiation and re-evaluation might be enacted. Specialist contractors,

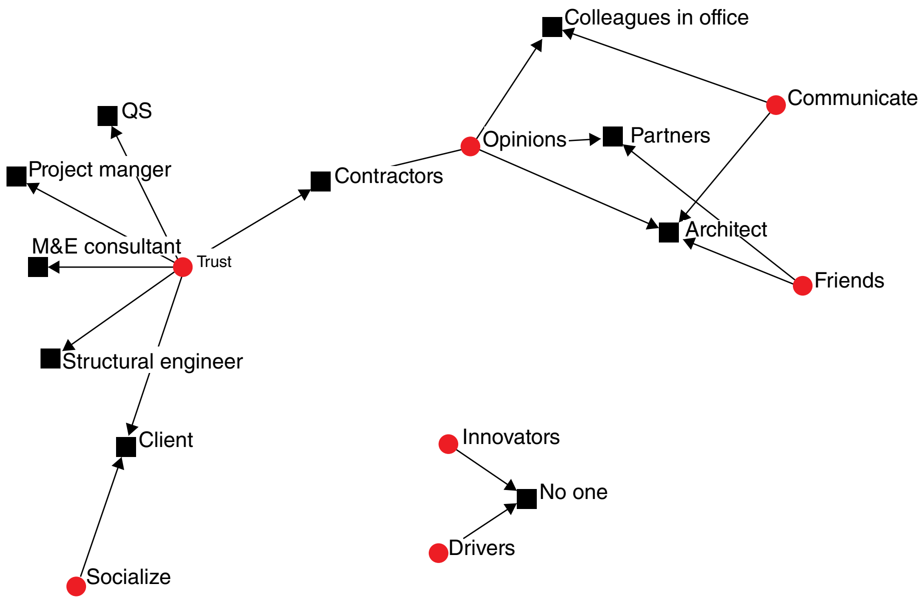

Figure 8.4 Network of Firms Enacting the Innovation Diffusion Process (not Artificially Bounded by One Firm).

mechanical and electrical contractors and the client appear to hold key roles associated with the innovation diffusion process.

Figure 8.4 is offered in stark contrast to Figures 8.2 and 8.3. This presents a firm that is isolated within the innovation diffusion process from other firms. The firm recognises no innovators or drivers and thus perhaps that the project, market sector or UK construction sector generally is somewhat stagnant. This may be a by-product of the *type* of projects the firm is engaged in or level of its experience and exposure to innovation.

Networks of Firms

Figures 8.2, 8.3 and 8.4 illustrate how a firm views the innovation diffusion process occurring across the network of firms with which they are engaged. The networks illustrate how firms perceive their relationship with other firms, and how they view the roles of other firms. This is especially important for the smaller, regional firms that have limited resources to try things outside their expertise, because they will have to draw upon firms with complimentary capabilities and knowledge in order to be innovative and to diffuse innovation. Such firms are typically embedded within a geographical location, *making up* the very fabric of what is the construction sector in that location (Maskell et al., 1998). All of the actors noted in Figures 8.2, 8.3 and 8.4 will have to interact with the innovation, and it is through those interactions of various stakeholders together with associated negotiations between them that the innovation diffusion process is enacted.

Innovation diffusion occurs across a network of firms (typically centred around a project that plays a driving or restricting role); thus, research and understandings offered centred solely on ‘a firm’ are unrepresentative of how the process is enacted in practice. Thinking about the ‘firm’ is helpful, as is illustrated in Figure 8.1. Understanding an actor’s immediate innovation diffusion network is useful, but also has limits associated with the reality experienced in a project-based industry, such as construction. It is when we consider who the drivers are and who the innovators and opinion leaders might be that the networks of firms suddenly become more relevant.

Sense-Making Framework

In order to bring the discussion of the connected themes within this chapter into focus, a sense-making framework is offered in Figure 8.5. The framework illustrates the notion of *networks of firms* as central to the innovation

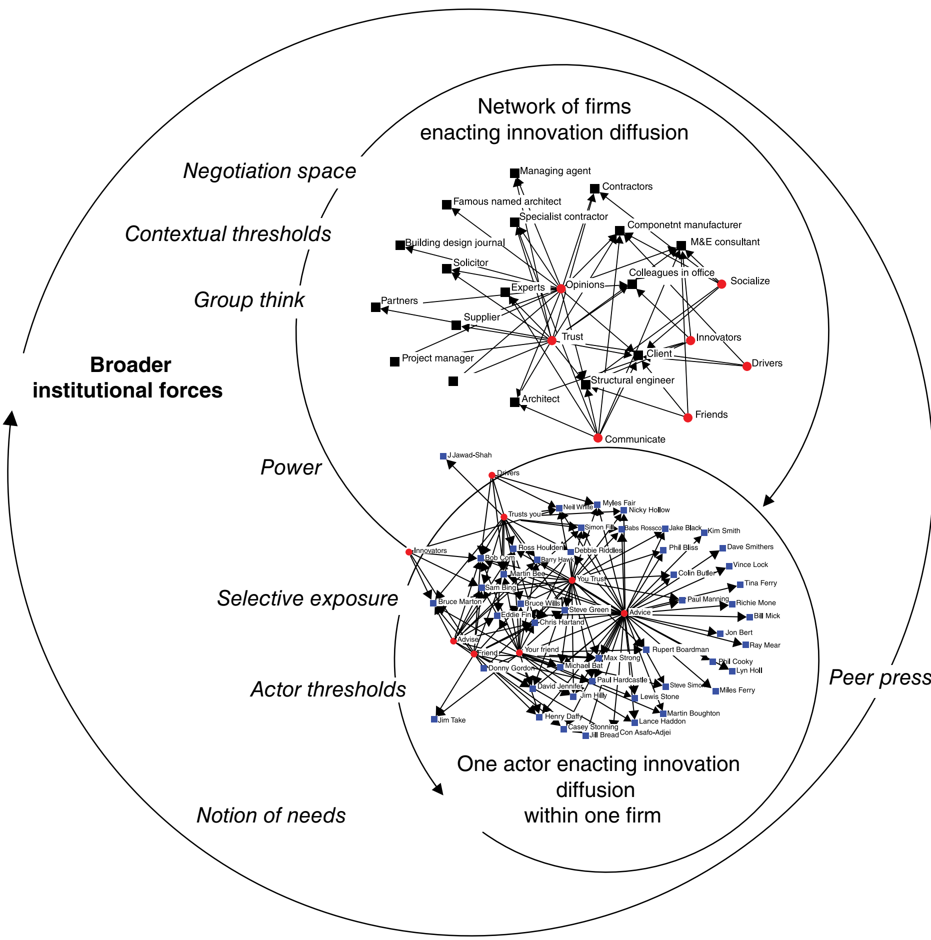

Figure 8.5 Innovation Diffusion Network – Within *One Firm*, Across the *Network of Firms* (developed from Larsen 2005, 2011).

diffusion process. However, these networks of firms are themselves not seen in isolation, and the framework acknowledges the interrelationship between an individual actor's network within one firm and with broader institutional and structural forces. The framework thus acknowledges the agency-structure perspective and the challenge of trying to understand innovation diffusion while seeking not to privilege either actors or structure.

The sense-making framework is a reinterpretation of Larsen (2005) and an evolution of Larsen (2011). It illustrates for the first time the interconnection between the actor within one firm, the network of firms involved (key element championed within this chapter) and the broader institutional and structural landscape (the forces by which the game is played, regulated, financed and standardized).

Conclusion

In this chapter, the position taken has been that there is much to learn regarding innovation diffusion from networks of firms for construction practitioners and academics alike. In doing so, it has sought to move beyond a single firm view and championed the notion of innovation diffusion occurring across a network of firms (associated through geography, market or a project).

The dynamic nature of the network of firms cannot be overemphasised. The practitioners within the firms and projects are constantly changing; the firm's structure and approach to its business are constantly changing, all of which has an influence on the shape of the network of firms engaged in a project. All actors have a role to play within the innovation diffusion process within their firm. This is non-negotiable for everyone, and actors may be completely unaware of the role they play or that they are even part of the innovation diffusion process at all within their firm, but they are. The role played is, of course, not fixed, but contextually situated and can change over time. This is a similar story for each firm that forms part of a network of firms engaged on a project, a market sector or a geographical area. Within that firm-level network (and thus really the client's project), each firm plays a role. Again, the role played is context specific to the innovation being diffused. Having accepted both of this issues, readers may wish to stop and ask themselves whether they actually have any idea at all where in these networks they or the firm employing them might reside.

It is hoped that by looking at network illustrations 8.2, 8.3 and 8.4, readers will begin to question where innovations are coming from, who is driving them, who is involved in the negotiation process and how they actually become aware of innovations and innovative practices. There is some evidence to support the idea that innovation does not always come from within one's own firm but perhaps from a firm within the local network. As such, there is a high probability that those considered *innovators* are actually outside one's own firm, but closely related within the firms network.

More practically, the UK construction sector would benefit from a more focussed yet sensitive approach in order to understand the diffusion of innovations in construction. Currently there is a lack of guidance for small- to medium-size, regionally based firms. There is no tool kit, no key performance indicator nor best practice handbook of how well 'networks of firms' operate in an innovative fashion, or how well 'networks of firms' diffuse innovation. Yet this is where innovation occurs and is diffused: across networks of firms. Certainly there are efforts within the sector to bring firms together through best practice clubs, events, and forums, but there is plenty of scope for improving this. What guidance there is often oversimplifies the nature of 'the firm', often viewing it as being a unitary entity with one coherent voice and certainly with little consideration regarding firms with regional subsidiaries, business units or even informal divisions from acquisition. The network diagram in Figure 8.1 could clearly be used to argue that point whereby firms are actually highly fragmented cliques of actors with different agendas.

The UK construction sector is beautifully diverse. It is possible to construct a bespoke multi-story building from the latest materials featuring smart facades, and at the same time a house built from straw bales and timber.

Our understanding of innovation within the construction setting is still in its infancy. Many have sought to develop our understanding of innovation, and there have been steps forward in research surrounding the subject. We begin to understand how and why innovation diffusion occurs in different settings and what different theoretical lenses can offer. The next phase of innovation diffusion research within construction management will hopefully take a marked step forwards while fully acknowledging the sociotechnical nature of the subject matter.

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9

Clients Shaping Construction Innovation

Kim Haugbølle, Marianne Forman and Frédéric Bougrain

Introduction

In dealing with construction innovation, this chapter takes as its starting point the concept that innovation in a project-based industry like construction differs from innovation in the manufacturing industry (see the discussion in chapter 2 of this volume). Even though procurement by clients is central to construction innovation, construction clients are not change agents per se. The agency of stakeholders in construction innovation was discussed in chapter 8, which employed a socio-technical perspective. However, more needs to be known in order to understand the agency of clients specifically with regard to change and stability in construction.

According to Dodgson, Gann. and Salter (2002), the literature on innovation management has dealt with four questions related to (1) the nature of innovation activities, (2) the sources of innovation, (3) the innovation process and (4) innovation systems on a national, regional, sector and technological level. Whereas the literature on innovation management has provided important and relevant insights, it mostly fails to acknowledge that the dynamics of construction innovation differ from innovation in manufacturing industry (e.g. Hobday 1998; Gann and Salter 2000). Hobday (1998, 2000a, 2000b) introduces the term *complex products and systems* (CoPS) as primary unit of analysis. To emphasise that certain industries such as some type of construction have distinctive characteristics apart from manufacturing industries. They are generally highly customised, engineering-intensive goods that often require several producers to work together simultaneously and with an extensive collaboration with clients and end-users.

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Public policies play an important role with regard to construction innovation (see, e.g. Manseau and Seaden 2001). In particular, public procurement has been promoted as a complementary and powerful strategy to drive innovation for sustainable construction along with more classical supply-oriented strategies (Edler and Georghiou 2007; SCI-network 2011). Such a demand-oriented innovation strategy has been promoted by not only a number of national agencies but also the European Commission through its Lead Market Initiative. In these strategies, construction clients are ascribed a crucial role as change agents.

It is not obvious, however, that clients are concerned with being change agents on behalf of the construction industry. One factor is that everyday observations suffice to give the impression that clients are already occupied with simply getting what they ask for from their consultants and contractors in the sector rather than pursuing innovation. More often than not, the problem in itself is to get what they want, in time, at the agreed price and with the quality they desire. For this reason, several national guidelines on exercising the role of a construction client have been developed in a number of countries (e.g. Erhvervs- og Byggestyrelsen 2008; Fristedt et al., 2012; Gann and Salter 2000). An additional point, which may be even more important, is that construction clients may not primarily be interested in building, but in organisational development of their own business. As Boyd and Chinyio (2006) pointed out, clients are often much more concerned with innovation in relation to their own core business than they are interested in stimulating innovation in the construction industry.

In recent years, some research on clients and innovation has emerged, notably through events such as the conference series 'Client's Driving Construction Innovation' (see Brown et al. 2005, 2006 and 2008) and the subsequent book by Brandon and Lu and their colleagues (2008). One of the contributions identifies seven criteria for classifying clients (Tzortzopoulos, Kagioglou and Treadaway 2008, pp. 62–63). Based on a literature review, these authors propose a construction client's taxonomy based on three triggers: policy demand, business objectives and personal aspiration (Tzortzopoulos, Kagioglou and Treadaway, p. 64). A contribution by Sexton, Abbott and Lu (2008) challenges the illusion of the all-powerful client's role in driving innovation and suggests a distinction be made between three roles: (1) a dominant client role in the guise of the lead user as introduced by von Hippel (1986), (2) a balanced co-production role following the work of Lundvall (1988) on user/producer interactions and (3) a passive client role consuming 'off-the-shelf' products and limiting their role in product and service development to feedback.

Whereas these studies certainly provide relevant insights, they lack the support of empirical evidence to a large extent. As Haugbølle and Boyd (2013) pointed out, the number of studies supported by both theories and substantial empirical evidence on how clients and users make a difference with regard to agency, governance and innovation are generally limited. This is where the present chapter aims to make a contribution; it bases the analysis of stability and change in construction on a specific theoretical perspective provided by a range of contributions in the field of science and technology studies (STS). Authors in this area are dealing with the issue of agency, that is, the dualism of actors and structures in relation to the role as owners, users, clients and stakeholders and their representatives (see the discussion in chapter 8). STS emphasise that technical objects and social relations are bound together and that actors and technology are co-constructed. Studies have shown that the users are actively shaping sociotechnical change, but also that agency is constrained by government regulations, gender relations and so on (see, e.g. Bijker, Hughes and Pinch 1987; Bijker and Law 1992; Oudshoorn and Pinch 2003).

Bijker (1995) introduced 'technological frame' as a theoretical concept in the analysis of interactions within and among social groups. To describe a technological frame, he proposed a tentative list of elements including goals, key problems, problem-solving strategies, requirements to be met by problem solutions, current theories, tacit knowledge, testing procedures, design methods and criteria, users' practice, perceived substitution function and exemplary artefacts (Bijker, 1995, p. 125). Even this long list of elements cannot but be incomplete, because some elements will be irrelevant for some social groups, and other elements may need to be added for others. Bijker (1995, p. 143) argues that because actors generally belong to more than one relevant social group, they will be involved in different technological frames at the same time:

> The degree of inclusion of an actor in a technological frame indicates to what extent the actor's interactions are structured by that technological frame. If an actor has a high degree of inclusion, this means that she thinks, acts, and interacts to a large extent in terms of that technological frame. It is expected that actors who are contemporaneously members of different relevant social groups will have different degrees of inclusion in the associated technological frames.

Based on the concepts of *technological frame* and *inclusion*, Bijker (1995, p. 277) proposes *a configuration model* in which sociotechnical change may have one of three alternative forms:

1. *No clearly dominant technological frame guides interactions*: This tends to lead to many different and radical innovations if the necessary resources are available to a range of actors.
2. *One dominant technological frame* guides interactions: It tends to lead to incremental innovations, because the dominant technological frame can insist on defining both problems and solutions.
3. *Two or more dominant technological frames guide interactions*: This tends to lead to incremental innovations in a dual sense, because they have to fit into both (or more) technological frames in order to be adopted.

This chapter explores how construction clients shape sociotechnical change in construction. More specifically, it (1) identifies methods for interaction between clients/users and the construction industry on sociotechnical change, (2) symmetrically deconstructs how sociotechnical change is configured by two dominant technological frames of production and consumption and (3) demonstrates how varying degrees of inclusion in the two technological frames constitute different settings for client agency with specific implications for sociotechnical change in construction.

Empirical Grounding

This analysis in this chapter draws on data from five case studies from three different countries: Denmark, Sweden and France. Despite similarities among the countries, there are also a number of important differences in their institutional contexts concerning, for example, the functions of actors, business structure and the role of insurance and technical inspection services, such as the French Bureau de Contrôle (see, e.g. Manseau and Seaden 2001; Winch and Campagnac 1995).

The five case studies were:

- BoKlok – industrialised housing concept
- HTH – web-based configurator of kitchens
- Rockwool – airtightness
- Maisons Macchi – prefabricated individual, low-energy houses
- Accor Hotels – renovating prefabricated hotels

The cases were selected for maximum variation, as suggested by Flyvbjerg (1991), and reflect differences in:

- *Construction business systems*: France as an example of an industry-driven system (contractors) versus Denmark as a profession-driven system (consultants) similar to that in the United Kingdom (Winch and Campagnac 1995; Winch 2000).
- *Business models*: Production-oriented business models versus service-oriented business models.
- *Product scales*: Complete buildings versus system components.
- *Types of clients and users*: Professional and non-professional clients and users during both production and use.

The case studies use multiple sources of information: interviews with key persons, documentary material, site observations and so on. Consequently, the project team developed a common guideline to ensure the collection of data on a number of pre-selected common themes to make comparisons and analysis possible. The themes included, among others:

- Institutional context
- Characteristics of the innovation process
- Effects on the construction business system
- Implications of findings

The five case studies were conducted as part of an international project called TRANS-USERS, Transforming the Construction Industry Through

User-Driven Innovation. The following description of the five cases studied is based on Forman, Haugbølle and Bougrain (2009), where more details on the individual case study is given.

Case 1: BoKlok – An Industrialised Housing Concept

BoKlok is an industrialised housing concept developed in the mid-1990s in a strategic partnership between two leading Swedish firms: IKEA, an industrial manufacturer of furniture, and Skanska, an international contractor. IKEA was looking for a partner to build affordable housing in line with its general vision of supplying affordable home furnishing. Skanska, on the other hand, was looking for a partner to develop a new industrialised approach to house building. Thus, the partnership was designed to challenge the traditional supply chain (http://www.boklok.com).

The concept has a number of striking features with regard to clients and users. First, it was developed on the basis of classical customer research with regard to affordability, type of household, location and so forth. This research also included post-occupancy evaluations (named Positive Customer Index [PCI]) and online platforms for sharing user experience. Thus, users were primarily considered to be information sources for the BoKlok team. Second, the concept was based on the intimate knowledge of IKEA's designers regarding how people wanted to live. This knowledge had a direct bearing on the design of homes with plenty of air and light, balconies, effective use of floor area and so on. This approach differs substantially from the usual design process targeted at a specific client and with a specific location in mind as development takes place among projects rather than within a project. Third, the housing concept used wood as the dominant building material, which allowed for extensive use of industrial production methods in a remote factory, and subsequent transportation to the site as 3-D modules for final assembly. Fourth, the unique sales process took place at special events at the nearest IKEA store where the actual owners were selected randomly (by way of a lottery).

The first four residential areas were built in Sweden in 1997. The concept has since been exported to other Nordic countries, the United Kingdom and Germany. Today, more than 4,000 homes have been built in more than 100 locations in five different countries. Expanding from the Swedish market into other housing markets, such as the Danish one, did, however, pose challenges to the concept. Recognising the differences in user requirements, architectural standards and so on made BoKlok partners ask Vandkunsten, a leading Danish architectural firm, to redesign the concept to increase the likelihood of acceptance in the Danish market.

Case 2: HTH – Do-It-Yourself Kitchen Configurator

HTH is the largest manufacturer of kitchen solutions in the Nordic region. The business model comprises three layers: factories, franchise sales stores and independent carpenters installing kitchens. HTH's business strategy has historically focussed on optimising production, which has led to a highly industrialised production based on just-in-time principles. However, in recent years, focus has shifted from production towards market relations. HTH operates in two markets, the professional and the private. Our analysis here does not deal with the professional market.

To meet the demands of private customers better, HTH has developed a web-based product configurator for private end-users themselves to configure kitchen solutions. Although the configurator originated as a tool for production planning used by consultants in sales stores, it is easy to use, which allows an interested user to draw a new kitchen in just a few hours. The web-based configurator is not a spectacular innovation in itself. Similar solutions can be found with competitors like IKEA and within the automotive industry. However, as Woolgar (1991) and Mackay et al. (2000) pointed out, software technologies may have more subtle effects than what appears at first glance. Obviously, a first direct effect was to use the configurator for designing kitchens. A second, subtler effect was the configuration of different user groups supporting the division of the private customer market in two:

- *The traditional market for kitchens*, *which is still the main market*: This market has users who are expected to consult the sales stores for assistance, whether or not they bring their own proposals designed with the configurator.
- *The do-it-yourself (DIY) market*, *which is a smaller*, *but fast-growing market*: The user in this segment is expected to handle the complete process of designing the kitchen, ordering elements an so on.

A third effect is the potential disruptive effect that the solution may have on the organisational structure. This, it would seem, can impact the basic organisational structure of HTH. A new business model more firmly directed towards the DIY customers via the configurator will challenge or even replace the existing sales organisation, in particular the business of the individual franchisees. Such a transformation may be difficult to accommodate within the current organisation of HTH.

Case 3: Rockwool – Airtightness

In 2006, the Danish Building Regulations introduced a range of new requirements and provisions for the energy performance of buildings, for example, the airtightness of new buildings, and two new low-energy performance classes. Meanwhile, an employee at Rockwool, the manufacturer of insulation materials, designed a new home for his family, which was meant to comply with these new building regulations. Although being a skilled carpenter and trained as a building engineer, the employee quickly faced a number of challenges.

Low-energy houses were not very common in Denmark at that time, but prior to the employee's building project, Rockwool had developed RockTæt, an airtightness programme with different products that would help meet the new requirements. A product manager realised that the colleague's private building project was an excellent opportunity to do real-life testing and share lessons learnt using the new airtightness programme with other users. Eventually, the employee not only conducted real-life testing of the airtightness products but also developed new technical solutions through his own practical problem solving. He creatively combined products from Rockwool with products from other suppliers into a more comprehensive low-energy building concept.

The communication department at Rockwool benefitted greatly from following and documenting the design and the building of the low-energy house. The department realized that at a time when the results were new to most building professionals and non-professionals, the story about the pilot building effort could became a cornerstone in the development of a novel approach to market Rockwool products. During the project, Rockwool identified a new type of end-user that it labelled 'Do-It-Yourself/Do-It-For-Me'. This constitutes a new group of users seeking information to qualify them to take charge of their own building projects, but still relying on professionals to do the actual work. Previously, Rockwool had mostly known of end-users indirectly through either wholesale offices or professional consultants, who traditionally have been Rockwool's most important target groups.

This case is an example of an employee acting in the dual role of employee and client/user. The combination of professional skills and user perspectives made this person a valuable intermediary between users and the construction industry, and, as such, he was in a position to contribute significantly to innovation in the industry. At first glance, this case is simply an example of an employee acting in the dual role of employee and client/user. But in a more profound sense, the case illustrates that the construction sector is full of people with a double inclusion in both the construction frame and the user frame. This double inclusion in two technological frames holds a potential for innovation that is not presently being utilised systematically by companies.

Case 4: Maisons Macchi – Prefabricated Low-Energy Houses

Maisons Macchi is a local French family-owned manufacturer of wall systems. Professional experience of troublesome construction sites, personal health problems and energy consciousness encouraged the owner and manager of the company to develop a concept of low-energy houses that went beyond the actual building regulation and to patent a prefabricated process 'MACC3' and to implement an ISO 9001: 2000 quality assurance system as the first and only builder of individual houses in the Alsace region.

The patented process MACC3 rests on a prefabricated insulation system consisting of a 30–50 cm layer of expanded polystyrene, which is pressed into freshly mixed concrete. At the first stage of prefabrication, fresh concrete is poured into the mould with spaces for windows and doors already in place. Electrical cables and an electrical heating system are also integrated in the walls. When the concrete has been poured, the insulation layer of polystyrene is pressed against the concrete in the mould. No other element is necessary for assembling the two elements. At the end of the production line, the prefabricated product is ready to be used.

The development of the prefabricated concrete elements and low-energy housing concept rests on a number of new partnerships. A leading polystyrene supplier was frequently solicited to deliver new products, which were integrated into the production. A collaborative agreement was signed with a German manufacturer in charge of prefabricating the walls. A partnership was set up with a financial institution, which granted a reduced loan of 3.5% for as much as €50,000 to every household choosing to buy a low-energy house.

The end-users did not participate directly in the innovation process but were constituted by representations of users made by Maisons Macchi. This concept is founded in the perceptions of user needs of the owner of Maisons Macchi and on the feedback generated through three questionnaires sent to house buyers as part of a quality assurance system.

Apparently, Maisons Macchi was ahead of its time in 2009. The diffusion of the concept has been very limited with only a small number of low-energy houses having been built. Indeed, houses built by using traditional masonry remain less expensive, and the provision concerning thermal insulation was not enforced until 2012. In the meantime, Maisons Macchi gave up producing low-energy houses and focussed on wall systems instead.

Case 5: Accor Hotels – Renovating Prefabricated Hotels

Accor Hotels is one of the world leaders in the hospitality market covering all segments from low-budget to upscale hotels. It has been a pioneer several times, for example with the then radically new low-cost hotel concept Formule 1, which was based on novel construction and management techniques. The commercial success and durability of the concept can be ascribed to an extensive marketing study carried out prior to the design of the hotel and an anthropological study by one of the project managers who stayed in low-budget hotels to understand customers' needs, expectations and priorities. As a consequence, the hotel chain was designed with a strong focus on the design of individual rooms rather than architectural aesthetics and common amenities (Kim and Mauborgne 1997).

In 2003, the managers of the low-cost Accor Hotels realised that it was necessary to adapt the brand to changes in the marketplace resulting in a fall in occupancy rate. To reverse this tendency, a refurbishment of the 282 hotels in the portfolio was launched to rework the brand's logo and redesign the rooms, cafeteria and common areas. The refurbishment project took place in 2007–2010 with ten contractors and five technical designers distributed regionally. To improve productivity and stimulate learning, the technical management of Accor Hotels introduced some novel elements into the process:

- Long-term framework contracts to ensure continuity of teams
- A plug–and-play approach with a repetitive and fast rotation process, in which only sixteen rooms were blocked at a time in order to keep the hotels opened

- A just-in-time approach with supply from several manufacturers, or each contractor could rely on a stock corresponding to the refurbishment of sixteen rooms stored on site
- The presence of an eleventh 'back-up' company to be called in if any contractor encountered difficulties

The standardisation of the hotels of the Formule 1 chain and the fact that most hotels were built during the same period made possible an industrialised refurbishment process. Even if such industrial refurbishments are unique in several respects, this case shows that clients can get better value when they play a proactive role during the construction process.

Findings

Key findings from the case studies are presented in the following.

Types of Innovation

A diverse range of innovation types and methods for interacting with clients/users are represented in the five cases. See Table 9.1 for an overview of the five cases, the type of innovations addressed and the methods and technologies applied to client and user interaction.

Table 9.1 Types of Innovation and Methods for Client/User Interaction.

Case	Type of Innovation	Methods for Client/User Interaction
BoKlok	Product and process: Industrialised housing concept	Customer survey
	Organisational: Joint venture	Positive Customer Index
	Marketing: Sales process	On-line platforms
HTH	Process: Web-based configurator	Configuration of two types of users
	Organisational: Reconfiguring existing organisation?	Sales consultancy and showrooms
Rockwool	Marketing: Story telling Product and process: Real-life testing and use descriptions Organisational: Critical consumers	Dual role as a user and an employee
Maisons Macchi	Product: Low-energy housing concept	Personal experience
	Process: Patented MACC3 process and ISO 9001: 2000 certification	Three types of satisfaction surveys Non-user
Accor Hotels	Organisational: (1) Long-term contracts, (2) plug-and-play approach, (3) supply-chain management (just-in-time) and (4) presence of a back-up company	Customer survey

All of the case studies involved more than one type of innovation. In line with the classification of innovations defined by the Oslo Manual (OECD and Eurostat 2005), examples of innovations represented by the five case studies are:

- Product innovation was found in the industrialised housing concept of BoKlok and the low-energy housing concept by Maisons Macchi.
- Process innovation examples are the patented MACC3 process by Maisons Macchi and the web-based configurator by HTH.
- Organisational innovation examples are the industrialised refurbishment strategy by Accor Hotels and the joint venture of BoKlok.
- Marketing innovation was based on story telling, as developed by Rockwool.

Two Technological Frames

With regard to client/user interaction, the cases encompass two main categories: direct and indirect representation. The cases with direct representation include sales consultancy in HTH and the dual role of user and employee at Rockwool. The cases with indirect representation of users include customer surveys as seen in the case of BoKlok, Accor Hotels and Maisons Macchi.

Several of the case studies illustrate the emergent character of user groups and the effects of user groups, whether these are achieved by chance or by design. The BoKlok case demonstrates how a detailed description of a future group of users was extracted from a carefully planned process involving surveys but still needed adaptation to a new local context when the concept was exported to other countries. Similarly, the case of Accor Hotels demonstrated that user groups can change over time and require adaptations of design concepts. An example of an outcome that was not planned is the development or discovery of new user groups, such as critical consumers and DIY customers in the cases of Rockwool and HTH. The Maisons Macchi case-study illustrates how non-users may undermine even the best intentions. A similar point has been made by Wyatt (2003).

Significant differences exist between the production and use of buildings. Two dominant technological frames can be identified: a construction frame focussed on the production of buildings and a user frame linked to the use or consumption of buildings, such as living, teaching, nursing, leisure etc. Refer to Table 9.2 for an overview of the content of each of the two dominant technological frames.

Clients as the Nexus Between Production and Consumption

Construction clients operate as a nexus that ties together the use and production of buildings. This nexus can take on three different settings, depending on the degree of inclusion of the construction client in either of the two dominant technological frames of production and consumption: (1) the client as a user with a high degree of inclusion in the user frame, (2) the client as a producer with a high degree of inclusion in the construction frame and (3) the client as an intermediary with inclusion in both frames.

Table 9.2 Overview of Technological Frames.

Elements	Production: Construction Frame	Consumption: User Frame
Goals	Buildings as an end	Buildings as a means
Key problems	Delivery on time, budget and quality	Supporting core business (office work, etc.)
Problem-solving strategies	Project management	Procurement of building
Requirements to be met by problem solutions	Defined in building codes, contract, drawings and descriptions	Emergent during building process
Time perspective	Focus on building process	Focus on time after construction
Current theories	Engineering and architectural theory	Varies with core business, if any
Tacit knowledge	Building practices	Core business
Experience with building activities	Repeated and exhaustive	One-off and shallow
Testing procedures	Control programme, technical inspections, etc.	Perceived and experienced
Design methods and criteria	Phase model	Comparison with 'old' days
Users' practice	Generic assumptions	Intimate and multifaceted knowledge
Perceived substitution function	Inappropriate facilities	Improved business, leisure, teaching, etc.
Exemplary artefacts	Successful projects/buildings	Compare with like-minded (peers, competitors, neighbours, etc.)

The Client as User

When the client has a high inclusion in the user frame and a low inclusion in the construction frame, the construction client will have a high sensitivity to the actual user needs, but they will typically be framed and phrased with a very high degree of specificity linked to that particular user. This will typically be the case in many conventional building projects (see Figure 9.1).

For the typical kitchen buyer, the web-based configurator by HTH can be viewed as an attempt to configure and maintain the client as user. However, for the new DIY segment, the configurator can be viewed rather as a move towards a setting that empowers the client to be an intermediary.

The challenge for construction companies as well as manufacturers of construction products is to satisfy individual needs and at the same time develop more generalised services and products aimed at a wider group of users. For construction companies, but not necessarily manufacturers of construction products, the potential drawback is a lack of attention and responsiveness to more general user needs, which might form the basis for developing services and products that would be relevant to other groups. Thus, the likely outcome of innovation activities among construction companies with a high degree of inclusion in the construction frame will be the development of capabilities of flexibility and adaptability in order to meet the changing nature of specific user needs.

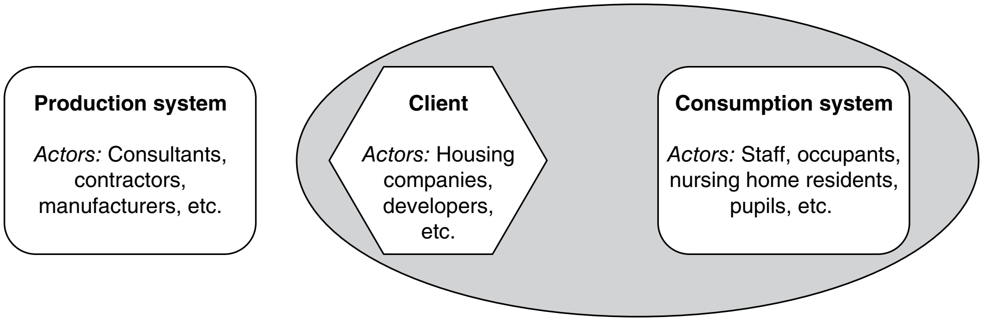

Figure 9.1 The Construction Client as a User.

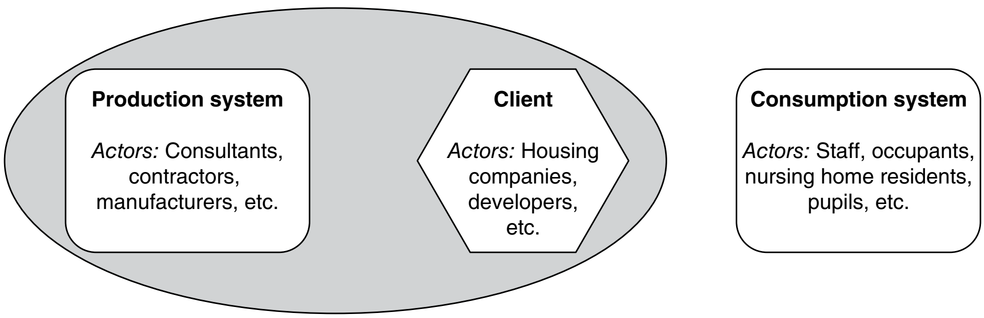

Figure 9.2 The Construction Client as a Producer.

The Client as a Producer

When the client has a low degree of inclusion in the user frame and a high degree of inclusion in the construction frame, the construction client will have a high degree of sensitivity to the production-oriented needs, which will typically be framed and phrased with a low degree of specificity linked to particular users. Effectively, the client function will be absorbed by the construction firm, whereas users may be represented, for instance, through surveys of user needs as applied by BoKlok, and in the perceptions of user needs by key actors in the production system of Maisons Macchi (see Figure 9.2). As users in these cases are reduced mainly to sources of information for production purposes, innovation activities among construction companies and manufacturers will be more general in character in order to develop products and services that embrace as many potential users as possible. This will be done in order to obtain the advantages of economies of scale and to increase the learning effect of repetition. Moreover, innovation activities will rely on patents and other types of protective measures of intellectual property rights.

The Client as an Intermediary

When the construction client has a dual inclusion in the construction frame and the user frame, the client may have a moderate sensitivity to needs in both technological frames. Consequently, the client may operate as an

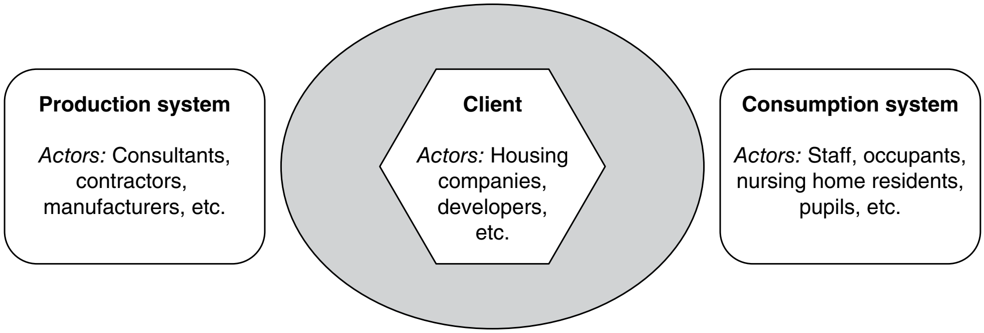

Figure 9.3 The Construction Client as an intermediary.

intermediary between production and consumption (see Figure 9.3). This may be the case with a professional construction client, such as the hotel operator Accor. Another example is the Rockwool employee who was acting in the dual role of employee and client/user.

The construction client may be able to digest and distil user needs and describe them in such a way that innovations may be developed. The innovation process may either carry the characteristics of being a co-creation process in which the client and construction firms jointly develop new solutions or a market-pull process with the construction client as either a lead user or a locomotive pulling the industry to change by setting stringent requirements.

Conclusions

The lessons learned from the five case studies point to a relationship between the governing role of clients and the implications for sociotechnical change in construction that depends on the identified agency of the three different settings. In response to these different agency settings, a client may pursue three different governance strategies, which are likely to have implications for innovation: (1) Clients specify particular needs, (2) clients are sources of information for innovation, and (3) clients act as locomotives or co-creators (see Table 9.3).

Drawing on social constructivist thinking in general and Bijker's concept of technological frames in particular, we have discussed how construction clients may impact construction innovation by influencing sociotechnical change in construction. We emphasise three main lessons learned.

First, a diverse range of methods for interaction between companies and clients/users on sociotechnical change have been highlighted in the five cases. These interactions have contributed to a broad range of innovations: product innovations, process innovations, organisational innovations and marketing innovations.

Second, sociotechnical change has been symmetrically deconstructed as we have proposed to see it as shaped by two dominant technological frames: one of production and one of consumption. The former is focussed on the production of buildings, the latter on the consumption or use of buildings.

Table 9.3 Role of Clients and Implications for Sociotechnical Change in Construction.

Agency	Governance	Implications
1. Client as a user	Specificity of needs	Adaptability and flexibility to meeting user needs
2. Client as a producer	Users as sources of information	Patents and other intellectual property rights
3. Client as an intermediary	Locomotive or co-creation	Potentially setting new industry standards

Third, we have demonstrated how varying degrees of a client's inclusion in the two dominant technological frames constitute different positions of client agency with specific implications for innovation. These three positions are (1) the client as a user with a high degree of inclusion in the user frame, (2) the client as a producer with a high degree of inclusion in the construction frame and (3) the client as an intermediary, positioned between consumption and production and being included in the construction frame as well as the user frame.

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10

Innovation in Road Building: Removing Obstacles for Diffusion of Novel Building Products

Timothy M. Rose and Karen Manley

Introduction

It is widely agreed that innovation can have a positive impact on performance at both the construction project level and a strategic industry level when the adoption and implementation of novel products and solutions is done in a systematic and contextually driven way (see Gambatese and Hallowell 2011; Slaughter 1998). Acknowledgement of the desirable benefits of innovation results in construction firms placing greater emphasis on ways to strategically manage innovation within the unique context of construction production (Aouad et al. 2010). However, innovation introduces complex challenges that can significantly impact construction production performance. These challenges differ from those encountered from say, the manufacturing industry, and include (1) the unique and novel characteristics of the constructed product, involving a wide range of specialised professionals embedded within a complex production system and (2) high risks associated with failure and requirement for long-term durability that leads to conservatism towards trial and error approaches (Blayse and Manley 2004; Nam and Tatum 1989).

Innovation in modern road infrastructure projects relies heavily on government agencies as clients. (See the discussion of the client role in chapter 9.) These agencies are traditionally risk-averse, well-informed recurrent clients. These agencies typically drive a design-bid-build procurement approach based on open tender, lowest-bid selection. According to Caerteling et al. (2011), this approach has constrained innovation and exploration by pushing firms towards a narrow focus on innovation that will minimise up-front costs, often at the expense of whole-of-life costs. (The effects of

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procurement models on innovation are discussed also in chapter 12). Additionally, the fragmented project-based nature of road construction production has discouraged investment in innovations that offer benefits beyond single projects. Although the road construction sector utilises equipment with high technology components, the work process is often based on implicit learning and tacit knowledge, driven by improvisation and inventiveness on site rather than long-term investment in innovation and R&D (Caerteling et al. 2011).

These types of challenges have constrained innovation at an industry level at a time when firms need to deliver larger and more complex road infrastructure projects in response to more sophisticated demand. Innovation is needed more than ever in response to strong growth in such demand. For example, in Australia, the total value of engineering investment in the pipeline was estimated at A$128 billion in 2013, representing more than eleven times that of ten years prior (Austrade 2013). In response to increasing demand, a strong Australian manufacturing industry is undertaking significant research and development (R&D) (ABS 2013), providing a steady flow of new innovations relevant to the road industry. Despite this strong supply of product innovations, adoption rates in the Australian road industry remain low, because of the presence of significant obstacles to innovation diffusion (Rose and Manley 2012).

The literature contains very few studies that examine the drivers of new product adoption in the road industry, and none that employ focus groups to develop consensual solutions to acknowledged innovation barriers. Furthermore, anecdotal evidence suggests that industry practitioners lack operational guidance concerning how they can encourage innovation at project level. This is particularly true for government client representatives who can potentially play a major role in championing new technology for adoption on road projects. Instead, the industry tends to operate in silos with resultant uncertainties about how the innovation system could be optimised. Information flow between organisations and between projects is restricted. In light of these knowledge deficiencies, this chapter provides practical advice and direction for government and construction industry organisations to improve innovation diffusion across the road construction industry.

The study focusses specifically on the diffusion of innovative products in road construction projects. According to OECD (2005), innovations can be defined by their degree of novelty categorised as new to an organisation, industry or the world. The focus here is on product innovation that is new to the road construction industry. Product innovation is defined as 'good[s] or service[s] that [are] new or significantly improved [for the road construction industry] with respect to characteristics or intended uses. This includes significant improvements in technical specifications, components and materials' (OECD 2005, p. 48). Product innovation in road construction often comprises new material development, such as high performance concretes and asphalts, geosynthetics, or fibre-reinforced polymer composites. Other examples include advances in intelligent network technologies, lighting, and damping and energy dissipation devices. New road construction products such as these are introduced to the market by product suppliers with other stakeholders (contractors, consultants and clients) acting as brokers and adopters of the new product in the diffusion process.

This chapter addresses the following research question: 'How can the most significant barriers to new product diffusion in the road construction industry be overcome'? The answer to this question should focus on both demand-pull innovation and supply-push innovation. Such a distinction represents end points in old linear models of the innovation process. Today, innovation is usually conceptualised to have occurred within a product system involving many feedback loops between participants (Manley 2003). A good example in the construction context is Gann's seminal framework (Gann and Salter 2000).

The scope of this chapter is product diffusion by the main actors in Figure 10.1. In defining the boundaries of the construction industry, the authors consistently take a broad view with the overall orientation of this book. Rather than considering the narrow statistical boundaries often applied to the industry, the product system view reflected in Figure 10.1 is adopted. The system view of construction activity provides a contribution to gross domestic product (GDP) that can be more than double that of the industry more narrowly defined (Department of Industry Science and Resources 1999, p. 7). This is so because the traditional definition used in national accounting typically comprises only four sectors: engineering construction, construction trades, residential building and non-residential building. These sectors cover only the act of construction; they do not cover the means of construction.

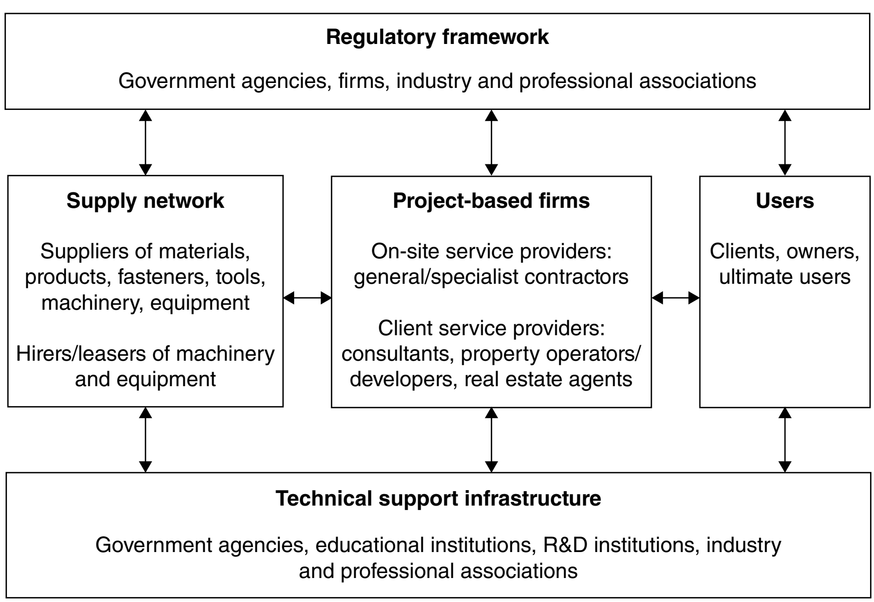

Figure 10.1 Participants in the Building and Construction Project System. Based on Gann and Salter (1998).

A system view of the industry takes into account other critical sectors that supply materials, components, products and services. Once the indirect income generated by dependent industries is taken into account, the contribution of construction activity to national economies increases significantly (Sedighi and Loosemore 2012; see also chapter 5 by Loosemore in the present volume). Our examination of product diffusion obstacles in the construction industry accounts for participants in this broadly defined system.

Focus groups were employed to address the research question. This work presented in this chapter represented the final stage of a larger research program. Originally, a large quantitative industry survey was undertaken to rank problems that were seen to constrain innovative product adoption in the Australian road industry. The list of problems used in the survey had been generated by an earlier interview program conducted in 2010 (see Rose and Manley 2012). In total, 865 survey questionnaires were distributed to senior managers representing their respective organisations across the road construction supply chain. Overall, 212 usable responses were received, providing a response rate of approximately 25%. This was an important exercise for policy-makers and comprised one of the largest innovation surveys of the road industry ever conducted globally. In summary, the survey identified two key problems that were ranked as the most important to be addressed by respondents across four key supply chain sectors surveyed, namely product suppliers, consultants, contractors and government road agency clients. The key problem areas identified were:

1. *Restrictive tender assessment*. This problem relates to the restrictive nature of the tender process discouraging product innovation, including a shortage of time and other resources to approve non-conforming products (as a part of a tender submission) and the overemphasis on up-front costs.
2. *Disagreement over who carries the risk of new product failure*. This problem relates to a general disagreement across industry stakeholders about how new product risks should be managed, which impacts on the willingness to propose and approve innovative products for use.

Drawing on the 2011 survey results, the broad objective of the focus group research was to unite key industry stakeholders involved in the diffusion of innovative road products, and to 'brainstorm' key initiatives from a whole of industry viewpoint to address the two key problem areas. The focus group study responded to an identified operational need within the Australian road industry to develop strategies to increase new product diffusion.

Methods

The focus group program was conducted in 2012 and involved three workshops, each of three hours duration, conducted in three Australian mainland states. The overall number of focus group participants was forty, comprising eleven suppliers, nine consultants, ten contractors and ten clients across the three focus groups. The research population (from which the focus group participants were drawn) was defined as key organisations in the delivery of Australian road construction projects across four sectors: clients, contractors, consultants and suppliers. These sectors are defined below:

- *Clients*: government managers responsible for project management, risk management and budgetary management – providing the link between governance, regulation and project management decisions.
- *Contractors*: main contractors responsible for the construction process and input to the design process, and trade contractors responsible for management of various trade packages on projects.
- *Consultants*: responsible for specific design areas such as engineering design development and management.
- *Suppliers*: responsible for the manufacturing and/or distribution of products to projects, procured by the contractor, consultant and/or client.

Key organisations were defined as those in the three states that appeared in the government road agency prequalification lists; others were members of three selected industry associations. The government road agencies were also included. The three industry associations included Cement Concrete and Aggregates Australia (CCAA), Australian Asphalt Pavement Association (AAPA) and Consult Australia. These associations were chosen for inclusion in consultation with the industry partners working with the researchers. The selected associations were considered to be the most important to road project innovation outcomes in Australia. CCAA and AAPA are the most significant product suppliers by value and volume on Australian road and bridge projects. Consult Australia covers most of Australia's engineering consultancy firms that play a major role in product innovation. This population frame was consistent with the original survey study to maintain external validity and allow researchers to compare results across the two studies.

Within the research population frame, effective selection of participants and group composition is critical to the robustness of the focus group approach because it affects compatibility, cohesiveness and group motivation (Fern 2001). Focus group participants were purposefully selected and invited through project partner referrals to industry association and state government road agency contacts across the research population. This included senior managers represented on state government industry boards. Approximately forty-five suitable candidates were invited to attend the focus groups, with forty accepting the invitation. To maximise research validity, each sector was represented by at least two participants in each focus group session, with at least eight participants in each of the three focus groups. This sample distribution provided sufficient data variation, while maintaining control over the complexity and volume of data. In all cases, focus group participants were operational managers with experience in new product adoption processes.

Participants were purposefully selected to take part based on their ability to strategically discuss the industry problems, and their willingness to embrace the ethos of the focus group approach. Many focus group participants had previously shared road construction project experiences with other participants. Barbour and Kitzinger (1999) support this approach and argue that 'bringing together people on the basis of some shared experience is often most productive' (p. 9). In many cases, the researchers spoke with potential participants prior to the workshops to gauge their suitability in the context of each group's composition across the three groups.

The three focus groups were all managed by the same expert facilitator. A discussion guide was developed by the researchers for the facilitator. The guide provided direction on how the focus groups were to be conducted and a general outline of the direction and type of questioning to be undertaken. This included question cues for steering the discussion and probing for further information. Additionally, participants were provided an introductory brief one week prior to their group meeting to encourage them to prepare and maximise their contribution to the discussions. The facilitator had extensive experience in road project design and delivery, and as a fellow expert worthy of respect, he promoted the development of rapport with the focus group participants, and encouraged participants to openly communicate their ideas, views and opinions. The facilitator was also selected on the basis of personality and the ability to generate open discussion. One of the authors was also involved in all groups to observe, take notes on emerging themes, record any personal impressions and direct the facilitator in refining the focus group approach.

To maximise validity of the focus group data, the facilitator and researcher also actively sought to break down pre-existing hierarchical norms across the focus group participants, because hierarchies within groups can inhibit the contributions of certain participants. Bias due to pre-existing hierarchical norms cannot be completely discounted in a focus group environment; however, such influence was minimised by promoting equal opportunity and confidentially across participants. Similarly, a major research challenge was minimising focus group bias due to varying stakeholder interests. To minimise this type of bias, participants were purposely selected on their likely ability to discuss problems from a strategic whole industry perspective. Although it was important for the facilitator to encourage the open communication of ideas, views and opinions, the objective was to reach a consensus across the group on jointly agreed solutions. Thus, the focus of the group was shared solutions to the obstacles that impact all project stakeholders. Additionally, the facilitator managed and minimised 'dominance' bias (the negative influence of a dominant, extremely verbal personality) by allowing the participants equal opportunity to openly communicate their ideas and opinions. Finally, the researchers minimised 'expectancy' bias (due to varying expectations of the purpose of the focus group) by providing a short text to participants setting forth the focus group vision, objectives and expected outcomes.

The purpose of the focus groups was to identify the solutions to the two key obstacles to the diffusion of new products in the road construction industry. Manual content analysis of results was undertaken; this is a commonly used technique for analysing qualitative data in the social sciences area. It provides rich interpretations through the systematic and objective review of communication (Krippendorff 2004). Manual content analysis of the focus group transcripts and field notes was conducted to aggregate and categorise the most frequently cited initiatives to address the two pre-defined problem areas across the three focus groups. Analysing aggregated data across the three groups was appropriate, as the research study focusses on identifying key project drivers from a 'whole of industry' viewpoint as opposed to initiatives that may apply in a specific context (e.g. state government jurisdictions). When categorising the data, care was taken to identify initiatives that were (1) frequently and broadly cited, (2) limited to the most significant and (3) mutually exclusive.

Findings and Discussion

Table 10.1 presents the four key drivers to increased innovative product adoption on Australian road construction projects identified by the focus groups, namely: (1) pre-project product certification, (2) past innovation performance assessment, (3) earlier involvement of product suppliers and road asset operators and (4) performance-based specifications.

Table 10.1 Key Product Innovation Drivers, Australian Road Construction.

Solution	Description
Pre-project product certification	Development of an innovative product certification process outside the tender stage to alleviate project resource constraints. This process may involve the development of an independent certification body representing government and industry interests to assess and confirm performance and comparative value of innovative products that may be outside current client road agency specifications.
Past innovation performance assessment	Greater emphasis placed on contractors' past innovation performance as a non-price tender selection criterion. This may offer further incentives for contractors who normally act as 'brokers' of new product knowledge to champion the uptake of innovative products for project benefit.
Earlier involvement of product suppliers and road asset operators	Earlier involvement of suppliers and road asset operators in project planning and design stages to improve product adoption decision making and better define the value of new products in comparison with existing products from a whole-of-life perspective.
Performance-based specifications	Increase the uptake of performance-based specifications, argued to provide more flexibility to adopt new products that previously have been non-conforming. Product suppliers should be encouraged to offer longer expressed warranty periods for new products to increase client confidence in product performance and offset liability, particularly under performance-based specification conditions.

Pre-Project Product Certification Process

The literature encourages construction clients to establish a transparent process for assessing alternative product and design options, and to provide the resources to fairly assess them (Sidwell, Budiawan and Ma 2001). Probity concerns and clients' lack of resources to effectively assess new product options can result in alternative tenders not being appropriately assessed. Furthermore, clients can develop the idea that contractors sometimes propose ill-thought through innovations at tender. The submission of unsubstantiated ideas ties up client resources, leaving less time for consideration of robust ideas. According to focus group participants, new product approval processes are currently slow because client agencies are required to accurately validate the performance of a product before its full-scale adoption. This tends not to suit the short-term constraints of a project tender process. Overwhelmingly, focus group participants agreed that a potential way forward for the industry to alleviate the project pressures constraining the acceptance of new products is to establish a product certification process outside the project tender process, drawing information for outside the project boundaries.

According to focus group results, a key feature of a product certification system is establishing an independent assessment body that has the broad range of expertise and support to accurately assess product performance. This could encourage greater information flow at the project level, because confidence in product performance can be higher. This body could also monitor the quality of testing, manage what types of applications should be considered for a specific product and maintain a database of long-term performance during broader product implementation.

Past Innovation Performance Assessment

Clients have the opportunity to set their expectations for contracted parties through early stages of a project, particularly through the tender selection process. For example, clients can set expectations through selection criteria that focus on proposing innovative options to meet specific project goals. The benefit of innovation-focussed selection criteria is that tenderers will be judged on their capacity to think laterally about innovative opportunities and the ability to deliver value adding options, establishing the expectation that innovation is a key objective for a project (Rose and Manley 2012).

Although greater investment in verifying product benefits may lead to improved adoption, there seems to be inconsistency and confusion about appropriate tender criteria for encouraging product innovation drawing from information outside the project process. In response to the question of how the road project tender selection process can be improved to encourage innovative product adoption, focus group participants agreed there was opportunity to further emphasise non-price selection criteria, particularly past innovation performance in areas such as contractor experience in championing new products that have had benefited project outcomes. Given that a contractor generally acts as a project innovation knowledge intermediary between suppliers, clients and consultants (Rose and Manley 2012), this may incentivise contractors to champion the uptake of innovative products with proven value to a project to provide competitive advantage on future project bids.

Focus group discussion suggests that access to readily available external information about tenderer past innovation performance is required to further promote new product adoption on projects. A barrier to change is the continued emphasis on direct project costs (focusing on the project) as the key driver in contractor selection. Clients can drive innovation by placing greater emphasis on the strategic value of incentivising contractors to champion new products, thus establishing a process to access accurate external information about past performance; setting the expectation that product innovation is a key project objective.

Earlier Involvement of Product Suppliers and Road Asset Operators

Significant benefits for proactively integrating key suppliers in early concept and design stages include leveraging suppliers' specialised technical knowledge to aid in effectively integrating various supplier components while retaining the flexibility to adjust product design to meet changing objectives (Bozdogan et al. 1998). As the key knowledge base for innovative products resides with manufacturers or distributors of those products, design innovation (involving integration of innovative products with existing systems) can be restricted if suppliers are not effectively integrated into the development of design. Similarly, the integration of the extended supply chain, including subcontractors, suppliers and end-users in early project stages can facilitate improved value engineering and promote the sharing of innovative ideas (Khalfan and McDermott 2006) while focusing attention towards the collective objectives of a project (Dulaimi, Ling and Bajracharya 2003).

According to focus group participants, the *embeddedness* of product suppliers and client road operators/maintainers in the project planning and design stages was seen to improve the project team's capability to judge the relative value of innovative products to be incorporated into a design. It was also seen to increase the quality of information available to the project client to inform innovative product value decisions at early project stages, including the tender stage.

Early involvement of the extended supply chain in design stages may be difficult because there is a risk that design consultants may look upon such involvement as interference rather than assistance (Eriksson, Dickinson and Khalfan 2007). Interestingly, a consultant focus group participant acknowledged that such consultants tend to be sceptical of supplier motivation when suppliers have a vested interest in pushing their innovation to succeed. To overcome this issue, clients should endorse new products to be integrated into design to lessen consultant scepticism. Such an approach better utilises the project knowledge base and informs decisions with greater accuracy, thus increasing the opportunities for new products that offer improved value for money.

Performance-Based Specifications

Project specifications provide the means for defining client construction requirements to a contractor by assigning separate and joint responsibilities for compliance. A specification forms the basis of the construction contract and should have clear, measurable and achievable requirements (Lobo, Lemay and Obla 2005). Generally, specifications play an important role by defining the quality of the delivered product and preventing disputes (Barlow 1999). However, it is argued that 'over-regulation' in construction can negatively impact innovation (Dubois and Gadde 2002; Hartmann 2006). For example, heavily detailed prescriptive specifications are argued to limit the opportunity for project organisations to propose alternative innovative solutions, because of a lack of flexibility to experiment and deviate from prescribed methods (Aktan, Ellingwood and Kehoe 2007). Such experimentation can lead to more effective or efficient delivery approaches (Gann, Wang and Hawkins 1998).

On the other hand, detailed prescriptive specifications can prevent ambiguity and provide an economical solution for repetitive outputs that share 'common, time-tested geometry, shape, form and materials' (Aktan, Ellingwood and Kehoe 2007). Prescriptive specifications are also acknowledged to be easier to implement from a design and performance measurement standpoint. Despite the intention of detailed specifications to control output, there are acknowledged challenges in achieving intended performance requirements under prescriptive specification provisions. For example, prescriptive parameters on the composition of concrete mixtures, such as maximum water-cementitious materials (w/cm) ratio or cement content, can potentially contradict intended or implied performance requirements because of variations in the materials employed from region to region (Lobo, Lemay and Obla 2005).

Rapid changes in materials, products and construction techniques have led to a loss of rationale in prescriptive provisions (Aktan, Ellingwood and Kehoe 2007). This has resulted in recent moves to introduce alternative ways to specify project expectations while affording contractors the flexibility to apply their technical knowledge to deliver the highest quality end product. Performance-based specifications are argued to place more emphasis on the technical and innovation experience of contractors and their suppliers, rather than focussing on their ability to provide labour, materials and plant to construct to a rigid, highly specified design (Ohrn and Schexnayder 1998).

A key advantage of performance-based specifications is the clear distinction of roles improving the capability of the project organisation to manage risk and effectively allocate resources. Simply, it affords the contractor responsibility to develop and apply the 'means and methods of construction of their choice, provided the end results meet the acceptance of the owner' (Ohrn and Schexnayder 1998, p. 26). For example, prescriptive concrete specifications will focus on the properties of the 'raw materials, mixture proportions, the batching, mixing and transport of fresh concrete, and the full range of construction operations from placing to curing'. Thus, a performance-based approach to concrete will fully describe 'the required performance characteristics of the end product, leaving materials selection, proportioning and construction means and methods up to the party contractually bound to comply with the specifications' (Bickley, Hooton and Hover 2006, p. 5).

According to focus group participants, increased uptake of performance-based specifications across government road projects may encourage greater project responsibility for functional performance outcomes and provide the flexibility required to develop and implement new products that previously may have been non-conforming under a prescriptive regime. This was seen to increase the capability of the project team to deliver innovative outcomes by allocating risk of innovative product adoption to the party best able to manage that risk under certain project conditions. Simply, performance-based specifications that define functional performance requirements are seen to provide contract parties the flexibility to experiment with new product options that may be non-conforming under existing prescriptive specifications.

Performance-based specifications should clearly specify functional criteria and compliance test methods to use to assess performance (Lobo, Lemay and Obla 2005). Despite the agreed benefits of performance-based specifications, consultant participants (who would be generally responsible for setting performance criteria) cautioned that performance-based specifications require client representative skill and adequate lead time to clearly specify functional criteria and to conduct accurate assessment to verify and enforce compliance. As illustrated with an example from sustainable building in chapter 6 in this volume, regulations and specifications will be dealt with differently by various stakeholders in a project, and contractors may often focus on the cheapest alternative solution fulfilling given requirements. Thus, it is no trivial task to accurately specify and test functional requirements in order to encourage contractors to explore product innovations in areas outside scope minimisation and cost reduction, thus diminishing opportunistic behaviour.

Conclusion

The diffusion of new products is influenced by the effectiveness of project organisational processes and internal and external information flows within and across the project organisation. The literature indicates that project organisations that are closely connected and successfully bridge innovation information from their external environment and within the project innovation knowledge bank are more likely to adopt technical innovations earlier. This chapter addresses the need to more accurately define project organisational drivers that influence the diffusion of new products at the project level in light of the broader industry environment. The chapter addresses a neglected empirical phenomenon that has greatly impacted the adoption of product innovation in the Australian road construction industry: the lack of operational guidance in what external and internal project initiatives are required to improve product innovation adoption that can have a direct effect on industry performance.

New product diffusion in a project organisational environment is driven by multidimensional factors, including the capacity of the organisation to exchange innovation information with their external environment, the complexity and dynamic capability of the project organisation to internally capture the depth and diversity of the innovation knowledge base and the individual attitudes of project leaders to facilitate adoption decisions. The research results suggest that closely integrating these concepts to explore innovation adoption drivers in road construction adds value.

As a practical implication, the focus groups results identified four key drivers to increased diffusion of innovative products in the Australian road construction industry. They comprised (1) the implementation of an innovative product certification process outside the project to alleviate direct project resource constraints, (2) external access to contractors' past innovation performance to be included in the tender assessment process, (3) early involvement of the extended supply chain in project planning and design stages, to inform the relative value of innovative products over existing options from a whole-of-life perspective and (4) increased use of performance-based specifications to provide flexibility to trial and adoption of new products, which have previously been non-conforming on projects.

Broadly, the empirical findings suggest that the road industry should be investing more in the effective transfer of innovative product knowledge to inform decision making; streamlining road agency regulatory processes to provide greater flexibility; assessing new products on their long-term value for money; developing new processes for assessing and certifying product performance and increasing the use of complementary project governance arrangements that offer both a joint approach to risk management and to reward organisations willing to invest in product innovation.

At an individual level, client representatives could be taking a stronger leading role in promoting product innovation through their behaviour and project expectations, focusing on the strategic value of adopting new products. The need for government clients, who are the major buyers of road infrastructure, to champion innovative product development is strongly supported in the construction innovation literature. To achieve this, clients need to both improve their knowledge base for accurately assessing innovative products according to value for money, and utilise opportunities to showcase new products on projects for long-term benefits.

It is anticipated that the focus group findings will inform the development of refined strategies and assist public policy targeting improved product adoption rates in the construction industry. The focus group results also provide a strong base for future research to develop and pilot these recommended initiatives to encourage improved innovative product knowledge flow. Furthermore, as this study has focussed on product innovation diffusion, it would be interesting to compare results of this study to a study of other types of innovation in this important infrastructure sector with the aim to improve the efficiency and effectiveness of road construction project delivery.

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11

Innovating for Integration: Clients as Drivers of Industry Improvement

J. W. F. (Hans) Wamelink and J. L. (John) Heintz

Introduction

The fragmentation of the building process and the involvement of a wide variety of disciplines during the sequential project phases are widely considered to be root causes of many problems in construction delivery. This includes high costs, late delivery and poor quality. Integration, it is held, will bring about greater efficiencies and more effective products than we have become accustomed to achieving in a highly fragmented industry.

The principle of integration in the building industry has had many advocates among both practitioners and academics (e.g. Howard et al. 1989; Nam and Tatum 1992; Dulaimi et al. 2002; Baiden, Price and Dainty 2006; Forgues and Koskela 2009; Gambatese and Hallowell 2011b). These advocates see integration as both an innovation in itself and as a means to stimulate other innovations. Integration is an innovation in that it consists of a wide range of new practises, organisational structures and technologies distinct from previous construction practises. More simply, integration is an innovation in so far as it is a ‘positive change as a result of new ideas’ (Gambatese and Hallowell 2011a). In the terminology employed in the introductory chapter 1 of the present volume, integration will be an innovation to the extent that it represents a lasting (or sticky) change in the established practises in the construction industry. Innovations in the form of process integration may also stimulate other innovations by providing channels of communication and social structures required for realising change. We concentrate here on the sense in which effected process integration itself constitutes innovation.

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Several studies have contrasted the highly fragmented structure of the construction industry and construction processes with the state of affairs in other industries (Brandon, Betts and Wamelink 1998; Kornelius and Wamelink 1998; Jørgensen and Emmitt 2008; Vrijhoef 2011; Lahdenperä 2012; Bektas 2013). In particular, Brandon, Betts and Wamelink conclude that one of the most significant differences between construction and other industries is the fact that, unlike in manufacturing, there are no stable supply chains and few strategic relationships in construction. (See the related discussion in chapter 7 of the present volume.) Each new construction 'product' requires a new 'factory' on a new site. For each project, the layout of the building site, the selection of subcontractors and the logistics are designed anew. This property of the production process leads to a project specific culture and attitude. Each project is treated as a unique event with little that can be carried forward in terms of techniques, procedures or strategic relationships (Bektas 2013). Traditional contracting methods militate against sustained collaboration and supply chain integration.

Since the early 1970s, both practitioners and scientists have proposed concepts and procedures to solve various problems related to the fragmented construction industry. Examples include the application of planning techniques, the formalisation of organisational structures, the creation of coalitions between designers and contractors in a building team, the implementation of a wide variety of management software tools, the building of information modelling, the use of integrated contracts and the implementation of supply chain management. Many of these ideas for improvement proposed during the last thirty years rely on the concept of integration. Processes are integrated. Organization structures are integrated. And tools are proposed that, it is said, will lead naturally to integrated processes.

For many decades, however, little progress was made in realising integration in practise, despite the fact that the technological and management tools were available. Innovations in process integration seemed to be stuck on the lower part of Tarde's S-curve of innovation diffusion (Kinnunen 1996). However, about ten years ago, the rate of take-up of innovations in process integration suddenly accelerated in the Dutch market. Three important areas of innovation leading to construction process integration emerged as increasingly powerful trends in the industry:

- Integrated project delivery
- Building information modelling (BIM)
- Supply chain management

The histories of each of these innovation domains will be discussed in the following sections.

Commencing in the early 2000s, major public sector commissioning bodies started using integrated contracts in an effort to eliminate the sharp distinction between design and construction and to force the various parties involved to collaborate much more closely. Since then, we have seen this become common practise in the infrastructure, civil, office and health care sectors, now overtaking traditional contracting. Government and private clients embraced integrated contracts despite the lack of conclusive evidence that such projects deliver significant benefits. In fact, it is only as a result of the increased use of integrated projects that researchers will be able to establish the advantages that integrated projects will actually deliver. This will soon be possible as, according to the 'Steunpunt Architectenopdrachten Ontwerpwedstrijden', integrated tenders overtook traditional contracting in the first half of 2013 (Architectenweb 2013).

The observation of a sudden change in the willingness to use innovations facilitating process integration raises these questions: What were the key factors that brought this about? And, why now? After all, calls for innovations in building process have been made since the 1970s. The objective of this chapter is to better understand what conditions made possible this sudden increase in the take-up of different modes of integration in the Dutch construction industry. The general basis for the analysis will be Rogers' theory of diffusion (1995). *Diffusion* is the process through which an innovation becomes widely used throughout a market. Rogers uses the word *diffusion* to describe the phenomenon on a social scale and on the scale of the industry or sector. He refers to the process by which individual firms make the decision to use particular innovations as *adoption*. Rogers clearly sets out why some inventions take off and some do not. He bases this explanation upon five intrinsic preconditions for willingness to adopt an innovation: relative advantage, compatibility, complexity or simplicity, trialability and observability. One would expect potentially useful innovations would always diffuse into markets. In practise, this often proves not to happen.

Based on the theory of diffusion and Winch's (1998) model of innovation strategies in construction, a framework will be derived to analyse the new developments on integration in the Dutch building industry through a review of studies of process integration by Dutch research institutes and universities. By examining the strategies that have led to the increase in take-up of innovations in each of the three areas of innovation in process integration, we will build a picture of the relative effectiveness of a variety of drivers and strategies for innovating in each area. We will then have a basis for suggesting which strategies may be useful in the future, either in stimulating the diffusion-desired innovations or in predicting which innovations will be most successful.

Theory of Integration

The term *integration* has been used in reference to design and construction processes and contracts in a wide range of senses. The Integrated Design and Delivery Solutions (IDDS) group of the International Council for Research and Innovation in Building and Construction (CIB) has produced a 'road map' that provides a structured overview of the wide range of meanings given to the word *integration* and of the relationships between them. From the diagram in Figure 11.1, it quickly becomes apparent that the various domains of integration are not autonomous, but interconnected and

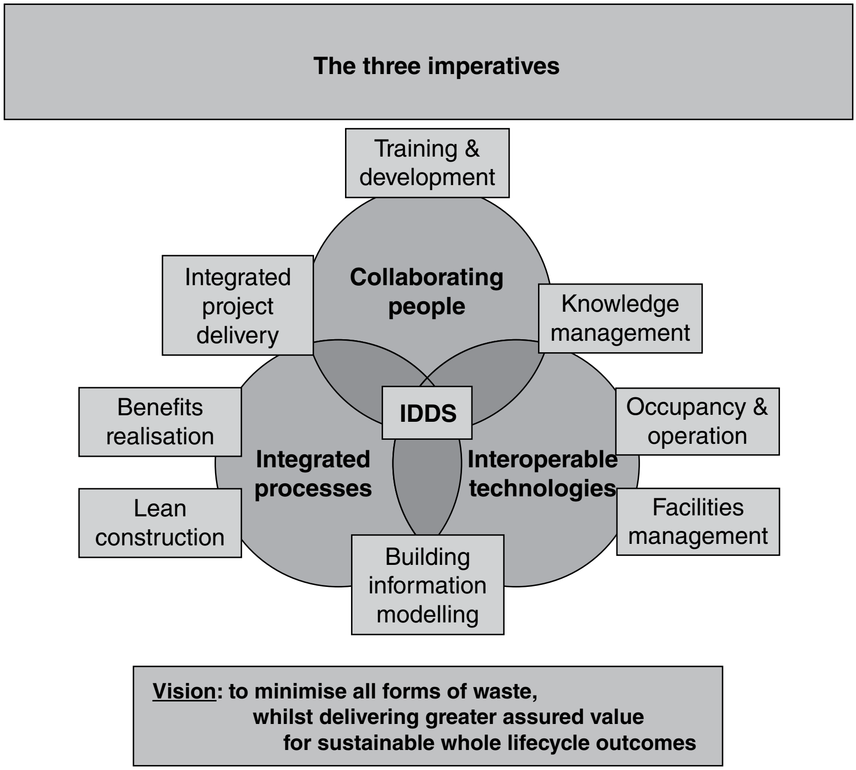

Figure 11.1 *The three imperatives, research areas and vision of IDDS.* (Owen et al., 2013).

interdependent. In their manifesto, the IDDS group dedicates themselves to this notion of an inter-related approach to promoting integration in the building industry.

> *The goal is a sector where people with traditional and new skills practice more collaborative and communicative processes, supported by pervasive, but nearly transparent, knowledge and information based technology. These professionals will be working towards continuous improvements across every phase and significant task of the project: conceptual planning and making the business case; all parts of design, supply chain, construction, commissioning; operation; retrofit; and even decommissioning and capturing the lessons learned into subsequent projects* (Owen et al., 2013).

Any meaningful progress in integration will require a coordination of processes in an organization but also between organizations. To achieve this as a branch requires that a variety of innovation strategies be employed at a variety of levels, from the entire market, between organizations and within organizations. Each of the domains identified above – integrated contracts, BIM and supply chain management – contributes only a part of the desired integration.

Drivers and Strategies for Innovation Diffusion

In order to understand this process and why the industry is now making progress in the diffusion of integrated approaches to the building process, we will need to draw on the theory of how innovations are disseminated throughout an industry. Aouad, Ozorhon and Abbott (2010) define *innovation* in general terms as the creation and adoption of new knowledge to improve the value of products, processes and services. Successful innovation, then, entails both the development of new ideas, processes or tools as well as the take-up of that innovation throughout an industry or sector. Others divide the process differently: 'Innovation in the construction industry requires three components: idea generation, opportunity and diffusion' (Gambatese and Hallowell 2011a). However, consistent with the fundamental understanding of innovation introduced in chapter 1 in the present volume, the point remains that for a change to represent a successful innovation, this change must be diffused in an industry and remain for some measurable period of time. Research in the dissemination of innovations in the building industry confirms that the construction industry is slow to take-up innovations if there is no specific driver or motivation to do so (Nam and Tatum 1997, Wamelink and Pries 2007; Whyte and Sexton 2011; Haugbolle, Forman and Gottlieb 2012. (See also the discussion in chapter 2 in the present volume.) An example of this is building information modelling (BIM). Although BIM technology has existed since the 1970s, it has only recently been widely applied in practise.

The diffusion of innovations is considerably influenced by the existence of factors known as *motivators, enablers* or *drivers*. Several researchers, including Nam and Tatum (1997), Winch (1998), Gann (2000) and Bossink (2004) have examined these factors. Gambatese and Hallowell (2011b) state that regardless of the process undertaken and the nature of the adopters, the diffusion of construction innovations does not occur in the absence of a motivator. Quoting Blayse and Manley (2004), Gambatese and Hallowell identified the following six key factors that influence construction innovation on projects: (1) clients, (2) production structure, (3) innovation networks, (4) procurement systems, (5) regulations and (6) organizational resources. These factors can be seen as corresponding to strategies, both intended and emergent, by which organizations in the construction industry attempt to implement innovations. Winch's (1998) model of innovation places these factors in the context of a social system, thereby demonstrating how they influence the diffusion of innovation (see Figure 11.2). Drawing on the work of Miller et al. (1995) on innovation in the flight simulation industry, Winch adapts their model for innovation in 'complex systems industries' to the construction industry. The model consists of a three-layer system in

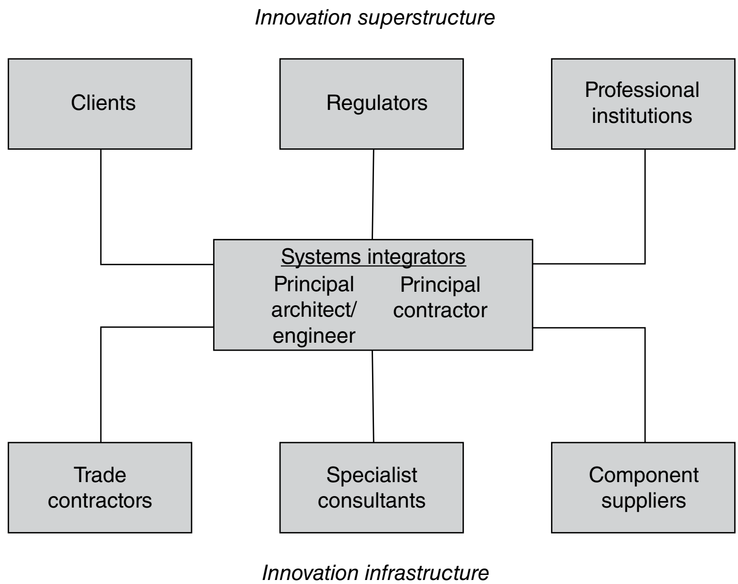

Figure 11.2 Winch's model of the innovation structures in the construction industry. (Winch 1998).

which system integrators (principal architects, engineers and contractors) are positioned at an interface between a superstructure (consisting of clients, regulators and professional institutions) and an infrastructure (consisting of specialised trade contractors, specialist consultants and component suppliers). The innovation superstructure governs the innovation environment, specifying demand, regulating performance and supplying knowledge processes and tools to the system integrators. The system integrators assemble complex systems products (flight simulators in Miller et al. 1995), using components and subsystems supplied by the innovation infrastructure.

In the construction value chain, clients can act as a catalyst to foster the diffusion of innovation by exerting pressure on the supply chain partners to improve overall performance and by helping them to devise strategies to cope with unforeseen changes (Gann and Salter 2000). Furthermore, clients have the ability to demand the adoption of innovation on a project-by-project basis.

Framework for Analysis

On the basis of the findings of the literature reviewed previously, a framework can be developed for the analysis of the developments in the three areas of innovation outlined above. Strategies on three levels for stimulating the diffusion of innovation can be identified: superstructure (market and governmental), infrastructure (contractors and suppliers) and system integrators (market parties playing an integration role). We can then analyse

Table 11.1 Framework for Analysis.

	Innovation Diffusion Strategies
Superstructure (clients, regulators, knowledge institutions)	
Infrastructure (trade contractors, suppliers)	
System integrators (building firms, architects)	

which strategies are effective at each level for each domain (integrated product delivery, BIM and supply chain management) and indicate potential success factors. We will determine which strategies have successfully led to the implementation of innovations. For each integration area (integrated contracts, BIM and supply chain management), both trade and research publications have been reviewed.

Integrated Project Delivery

The first design-build-finance-maintain (DBFM) projects in the Netherlands began in the late 1990s, initially in the infrastructure sector. Based in part upon experiences from the UK, their introduction was prompted by expected benefits: reliability in forecasting the date of completion and reduced costs for the government. The underlying idea is that time and money are saved by involving the market in making the project design, subject to commercial financing and maintenance terms. A good early example of such a scheme is the high-speed rail link between Amsterdam and Brussels. The contract was signed in 2001 and the line was completed in 2006. Given the size and complexity of the project that was worth €3 billion, this appears to have been a major achievement. Government calculations have suggested that the DBFM arrangement may have been about 5% cheaper than a traditional contract would have been.

There are also several comparable examples of road building projects from this period. In its 2004 business plan, Rijkswaterstaat – part of the Ministry of Infrastructure and the Environment and responsible for the design, construction, management and maintenance of the main infrastructure facilities in the Netherlands – wrote that a changing society was placing different demands upon government performance in its domain (Hoofdkantoor RWS 2004). Rijkswaterstaat's adoption of the new slogan 'more quality with fewer people' was meant to signal that the state retained its overall duty to build and maintain infrastructure, but that more of the actual work involved could be entrusted to firms in the private sector, which would in turn bring financing benefits. In fact, the business plan merely confirmed what the Rijkswaterstaat organisation had already been doing for some years: delegating many of its tasks to the market. The number of projects integrating design, build, finance, maintain, and in a number of cases also operation of facilities, has increased substantially since 2004 in the infrastructure sector in the Netherlands.[1]

One important aspect of this shift is that, from a very early stage, the government made sure that the appropriate legal framework was in place (CROW 2004). In 2000, the government issued a set of 'uniform administrative conditions for integrated contracts'. This was updated in 2005, taking into account the experiences gained during the initial pioneering phase. In addition, in 2002, the government published a model agreement for the application of integrated contracts.

Traditionally, building firms in the Netherlands have formed consortia to work together on major construction projects. For traditional contracts, the main reason is to spread the risks involved. In the case of DBFM(O) contracts, however, they have discovered that the consortium structure offers an additional benefit in that it allows them to recognise each other's added value. Interestingly, the consortia in this domain are made up of companies with complementary competences (design, construction, financing and maintenance), which together give the consortium its strength. Moreover, a genuine readiness to share experiences across project boundaries has given rise to a variety of joint initiatives, such as the public–private partnering organization PPS Netwerk Nederland (PPS Netwerk Nederland 2013). Such collaborative efforts encourage the use of integrated contracts and play an important role when disseminating relevant knowledge.

More recently, another major public sector commissioning body has decided to organise all its major projects as DBFM(O) schemes: the Rijksgebouwendienst, the Dutch Government Buildings Agency, part of the Ministry of the Interior and Kingdom Relations. This agency is responsible for managing and developing the bulk of the Dutch property portfolio: 7 million square metres of floor space in total, 70% of which the agency owns.

The agency's first DBFM(O) project, the renovation of the Ministry of Finance building in The Hague, went to market in 2005. The use of an integrated contract for that job achieved a cost saving of 15% compared with a traditional call for tenders. The renovation work began early in 2007, and the building reopened at the end of 2008, two months ahead of schedule. Such more or less consistent success stories are systematically monitored and reported by the government. Since 2002, the Minister of Finance has submitted biennial progress reports to Parliament (Ministerie van Financien 2012). These contain detailed descriptions of the projects commissioned by Rijkswaterstaat, the Government Buildings Agency and the Ministry of Defence, as well as an update on progress in implementing integrated contracts and recommendations to encourage their wider use. Reports of assumed successes in this field are readily forthcoming. In the most recent progress report (Ministerie van Financien), for instance, we find the following statement:

> The results achieved through DBFM(O) are good. Compared with traditional forms, these projects have thus far achieved an average surplus value of 10–15 per cent. That is the procurement outcome by

[1] The acronym DBFM(O) is used to designate such projects in the remainder of this chapter.

Table 11.2 Integrated Project Delivery.

	Innovation Diffusion Strategies
Superstructure (clients, regulators, knowledge institutions)	Consistent procurement of projects in DBFMO form (as faits accomplis). Development of information structure and materials Uniting organisations involved. Setting up clear and straightforward communications Development of supporting instruments, such as standard terms and contracts. Setting up communities of practice; sharing information.
Infrastructure (trade contractors, Suppliers)	
System integrators (clients, building firms, architects)	Setting up knowledge-sharing networks. Setting up internal knowledge centres for major projects and PPP projects. Setting up new legal entities to limit risks.

> comparison with the traditional method, as calculated using the Public Sector Comparator (PSC) DBFM(O) projects are consistently delivered on time and within budget. It has been calculated that a surplus value of almost €800 million has been recorded so far. And, based upon model calculations, it is expected that projects currently being offered for tender will add at least €100 million to that figure. Of course, the exact figure cannot be determined until after the contract has been awarded.

The report also mentions points requiring attention, however. In 2012, the main points concern financing and contract management.

Clearly, Dutch government policy has been to emphasise the success of DBFM(O). There have been few academic studies on its benefits, however. and, in fact, it should be pointed out that it is extremely difficult to quantify such benefits in terms of time and money in a scientific way. Indeed, a recent report from the Netherlands Court of Audit (Algemene Rekenkamer, the independent body responsible for checking that government spends public funds and conducts policy as intended) has for the first time raised questions about the actual benefits of using of DBFM(O).

Building Information Modelling

The principles behind BIM were known in the 1970s (Eastman et al. 1974a), when Eastman described how it should be possible to record all the information about a project (in all its phases and from all its participants) centrally in such a way that it could be accessed by everyone involved. BIM was indeed technically possible at the time, but very expensive and so neither practical nor cost effective. Research continued throughout the 1980s and 1990s. In the Netherlands, for example, substantial investments were made in IOP-Bouw, the Innovation-Driven Research Programme for the Construction Industry (Thissen and Stam 1992). This was a government-funded project for the development of standards describing processes and data models in detail. The intention was that the models would then be standardised and made available to the software industry; however, industry failed to agree on standards. Most players doubted the possibility of producing anything of practical utility or commercial viability from it.

Work on object-based approaches to BIM by the research group led by Frits Tolman in the Netherlands and Martin Fischer in the US (Luiten, Tolman and Fischer 1998) was showing that BIM systems 'following the integration concept allow for interaction between designers, construction managers and constructors.' Gradually, it was becoming clear that BIM presented powerful new tools for improving the collaboration of different parties in the construction process (Brandon, Betts and Wamelink1998). In the years after the new millennium, only a few small specialist players in the Netherlands could be found taking limited advantage of the opportunities presented by BIM. They were often young entrepreneurs who realised the potential and established a business model for BIM. But the resulting implementations were only partial (e.g. the application of 3-D with a limited number of basic functions, such as clash detection, and so on).

Driving this phase of innovation were new opportunities made available by the technology, as seized upon by enterprising and mainly young people. But Rogers' preconditions for the successful diffusion of BIM were still largely absent. The software was complex, difficult to learn and not compatible with other systems already in use. BIM systems were therefore difficult to try-out because the software was not widely accessible. Implementation would require a considerable investment, yet it was unclear who in the chain would benefit from this new development. As an innovation, BIM suffered from limited observability, i.e., it was difficult to observe or measure the relative advantage of implementing this software. As a result, few players were willing to attempt implementing BIM. Then, since 2006, the use of BIM gradually started to take-off in the Dutch market. Embraced rather earlier in North America, BIM has over the past five years become increasingly applied in Dutch practise. Large and medium-size architecture and construction firms are implementing it. Parallel to the UK experience, the advantage that students until recently enjoyed over commercial firms in this domain has disappeared. The industry itself (both architects and builders) now appears to be taking the lead and is returning to the universities with a new range of questions and demands. The universities are finding it necessary to redouble their efforts in research and, most significantly, education because industry demands not only BIM skills in recent graduates but also higher degrees of technical competence (Jaradat 2013).

The extent to which BIM implementations have been successful varies widely, however. In her research, Bektas (2013) notes that applying BIM to projects even now remains an 'emerging idea', rather than the result of an intended strategy on the part of management. BIM implementations are still not problem free and do not always achieve their intended goals.

A parallel development can be observed in the integration of BIM into new forms of contracts, such as those described in the previous section. People are discovering that the kind of integration and collaboration that integrated contracts and supply chain management are intended to deliver have specific advantages. Consequently, a 'market pull' driver has been added to the 'technology push' driver for applying BIM. In our view, this is a main reason that the use of BIM has been accelerating rapidly in recent years. The initial trigger for this came when major public sector commissioning bodies announced that they wished to implement it. For them, the key driver was a desire for easy access to data about their buildings after they had been completed for maintenance purposes. These bodies argued that it was unfortunate that the huge amount of information held by the builders and contractors by the end of the construction process was not available to them. Arguably, the BIM concept could form a basis for finding a solution to this anomaly. (It is interesting to note that the notion of asymmetric information, which is discussed in chapter 2 of the present volume, is quite foreign to the argument made by the commissioning bodies in this context.)

Several other collaborative development initiatives have been launched since 2006. Examples include building SMART and, more recently, the 5D-initiative. The latter is an independent task force established by the European Network of Construction Companies for Research and Development (ENCORD), which seeks to proactively coordinate and drive the development of software solutions that support process integration. The task force does this in collaboration with industry competitors, software vendors and research institutes. Focussing as it does upon the development of tools, this strategy arguably overlooks the preconditions for their use.

Table 11.3 Building Information Modelling.

	Innovation Diffusion Strategies
Superstructure (clients, regulators, knowledge institutions)	Setting up means to share knowledge. Developing supporting instruments, such as standard exchange formats; legal implications of using BIM. Setting up communities of practice: sharing information. Receiving major clients who ask for the use of BIM (since 2012 compulsory). Developing new integrated processes and forms of collaboration through the chain.
Infrastructure (trade contractors, suppliers)	Standardising suppliers supply of data of their products in 3D software.
System integrators (building firms, architects)	Starting with small pilots with reduced BIM functionality. Developing and sharing knowledge and experiences on BIM together in community of practices. Emerging of multi-project collaboration between these parties.

Another, specifically Dutch, example is the Building Information Council (Bouw Informatie Raad, BIR), which has set up a number of incentive schemes. Developments in this domain are also encouraged through European research programmes such as V-CON (Virtual Construction for Roads). This particular programme aims to establish a draft version of a standardised information and data exchange structure defining a first standard, which is to procure the necessary software and launch a Pre-commercial Procurement system (PCP) for the BIM server and software tooling. Standardisation, the goal here, is shared by many comparable projects.

Supply Chain Integration

The third area of integration innovation is supply chain management (Vrijhoef 2011). Inspired by the manufacturing industry, construction contractors have begun to pursue the expected benefits of forming strategic relationships with designers, subcontractors and suppliers that last longer than the duration of one particular project. Collaborating on multiple projects allows for the standardisation of products and processes. As well as creating interesting possibilities when it comes to the quality of the end product, long-term relationships also generate opportunities for every party in the a supply chain, specifically in terms of continuity and certainty. Participants have shown they are prepared to invest in each other's processes while abandoning traditional role distinctions. Rather than forming a new organisation for each project, a structure for a series of future projects is devised. Clients developing portfolios of projects have found this structure beneficial in terms of both processes and the end product.

In the Netherlands, supply chain integration began to arouse the interest of both the construction industry and the housing associations around 2007. The associations are responsible for about 40% of all the homes in the Netherlands, which they rent. With changes to the legislation governing their function, what can be seen as a latent dissatisfaction with their performance has induced the associations to introduce a stream of improvement initiatives. Examples include involving future residents in the design of their home, involvement of suppliers at an earlier stage and collaboration with trusted partners in a range of different sectors: 'management organisations, property developers, architects, local authorities, schools, care institutions and businesses' (Baalman 2013). The expected benefits of these initiatives are all similar in nature; reduced costs are mentioned particularly often. Other benefits include improved quality and reduced project duration.

What these examples have in common is the increased extent of cooperation between different participants in the entire process of construction – what is known in the Dutch market as 'supply chain management' or 'supply chain integration'. The relationships forged are based upon mutual trust, a dedication to common goals and an understanding of each other's individual expectations and interests. Housing associations and building firms have begun entering into strategic alliances in order to press ahead with this new

Table 11.4 Supply Chain Integration.

	Innovation Diffusion Strategies
Superstructure (clients, regulators, knowledge institutions)	Receiving clients' requests for increase of productivity in sequential projects. Starting with pilot project. Engaging in knowledge-sharing projects, also with building firms, etc.
Infrastructure (trade contractors, suppliers)	
System integrators (building firms, architects)	Making joint developments. Knowledge-sharing projects, also with client-organisations. Starting with pilot projects, gain experience and then share and combine.

form of collaboration to gain experience in joint projects. Programmes to share knowledge quickly (Platform Ketensamenwerking Woningbouw 2013) have been established, not just to share knowledge but also to communicate the participants' enthusiasm to the rest of the market. The strategy for implementation of change is to begin with small steps (pilots) and then to combine the results, first within the companies making up the chain in question, and later extending to other chains. Finally, it has been decided that these communities of practice should include researchers from various research universities and universities of applied science who are working on the effects of this integrated approach and comparing it with experiences in other industries.

Various success factors have been shown to correspond to experiences in the manufacturing sector (Cao and Zhang 2011). Among these are sharing information and know-how, making agreements concerning goals and incentives, pooling resources and joint communications and developing knowledge. In this case, no single initiator can be clearly identified, and technological changes appear to play only a limited role.

Conclusions

In all three areas of innovation conducive to construction process integration we have discussed, adoption of innovations appears to occur only if the superstructure plays a sufficiently strong role; clients and regulations are very important. (Compare the discussions in chapters 9 and 6 respectively, in the present volume.) On the infrastructure level (trade contractors and suppliers), no intended or emerging strategic action can be distinguished. On the other hand, system integrators (building firms, architects) have reacted to developments by starting pilot projects, facilitating exchange of experiences, building knowledge networks and other joint developments.

The vital role of the superstructure is obviously clearest in the case of integrated contracts for which the tendering is completely in the hands of the client organizations. It was of utmost importance that public sector institutions decided to embrace integrated contracting. Furthermore, BIM take-up has been accelerated significantly as a result of demand from large clients, making the use of BIM a firm condition in new projects.

Even though technology-push strategies were indispensable, they were not sufficient to trigger the use of BIM throughout the industry. (Compare this with the diffusion of micro-generation technology, discussed in chapter 6.) Only when the superstructure took the initiative and clients formulated a clear demand did the industry take steps in adopting innovations. Similarly, supply chain integration has also been taken-up when clients took a leading role and occurs significantly later in construction than in other industries. In all of the areas we have discussed, it has been the professional and demanding clients that have promoted innovation. It would seem that client organizations are in the best position to take the lead, at least if they are big enough to generate a significant demand and thus to change the market with which the contractors have to deal.

What we have seen, then, is that the clients' demands for greater integration in construction projects have created demand for integration technologies from system integrators in the construction industry, meaning, of course, information technology products and solutions, but also process and legal innovations.

We can account for the importance of superstructure strategies, clients and regulation in the diffusion of innovations in process integration by returning to Rogers' theory of diffusion. Arguably, because process integration innovations score low on all of Rogers' five factors influencing adoption, it is not to be expected that such innovations will diffuse rapidly. Until a particular demand is created for it, there is little for the construction industry to gain from these innovations. Thus, whereas over the long term there will be benefits for all parties from increased process integration, the short-term advantages to any individual supplier are not clear, and, given its high initial costs, may even be negative. (See the very similar argument made in chapter 3, which distinguished between innovation benefits gained by individual actors and benefits accrued by whole industries and societies.)

Given the singular importance of client demand for the adoption of innovations in the construction industry, it is clearly imperative to evaluate the benefits offered by integration as demonstrated in a growing number of completed projects. Research on project outcomes should try to map where the three forms of integration in projects deliver the most benefit. This research could serve to encourage clients to consider other desirable innovations. Whereas the technology-driven development of innovations in the building industry in our view undoubtedly will remain valuable, it is important to study what increase in performance clients are likely to demand in the future. Understanding potential demands will be an essential guide to predicting which new technologies are most likely to make the transition from interesting inventions into widely diffused innovations.

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12

Project Delivery Systems and Innovation: The Case of US Road Building

R. Edward Minchin, Jr. and Martha E. Gross

Introduction

The practice of organizing construction projects in separate design and production phases has dominated in the US transportation construction industry for a long time. In the design-bid-build (DBB) delivery system, an engineer designs a transportation project, and a contractor subsequently uses the completed plans to build it. Several factors, including clients' desire for fast delivery, growing traffic congestion and deteriorating infrastructure, have for some time driven demand for ever faster delivery. As discussed in chapter 11 in this volume, this development in the US parallels changes in the Netherlands (and other European countries) where organizational and contractual innovations introduced by demanding clients promote ever higher levels of integration in the industry in general, not least across the design and production phases of projects, of course.

In the 1990s, design-build (DB) was introduced as a fast-track alternative to DBB and has now become a viable option. Within the last decade or so, public-private partnerships (PPPs) and construction-manager-as-general-contractor (CMGC) have been introduced and used by a few state transportation agencies. Recently, initiatives under the banner of Every Day Counts have been issued by the US Federal Highway Administration (FHWA) to encourage fast-tracked project delivery. This has resulted in state transportation agencies' increased focus on effectively leveraging innovation, which Slaughter (1998) defines as the 'actual use of a non-trivial change and improvement in a process, product or system that is novel to the institution developing the change'.

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This chapter will probe the extent to which each of these three fast-track delivery systems (DBB, PPP and CMGC) incentivises innovation, because prior research clearly argues that choice of delivery system plays a key role in driving or hindering innovation in construction. Blayse and Manley (2004) listed project delivery systems as one of the six primary factors influencing construction innovation and identify 'the promotion of innovative [project delivery] systems to enhance cooperative problem solving', as a strategy that is 'widely acknowledged as important to innovative outcomes'. Gambatese and Hallowell (2011) noted that owners 'exhibit great influence over the innovative capacity of construction projects through their … project delivery method selected…'. They further proposed that project delivery methods that 'encourage phase overlap (e.g. DB), shared goals and contracting strategies have a greater potential than traditional ….projects to achieve innovation success on construction projects'.

Design-Build

System Description

The DB delivery system, as applied to transportation construction in most US states, is a fast-track approach in which construction may commence well before the design is completed. The inarguable advantages of DB are that it (1) reduces the time from project conception to completion (as would any fast-track system), (2) provides the owner with one point of contact (the design and construction functions are handled either by one firm capable of both or by a joint venture between firms capable of one or the other) and (3) involves the contractor in the design. The contractual relationship between the parties can be seen in Figure 12.1.

Both academic literature and empirical evidence indicate that the DB system provides a high degree of encouragement to innovate. Each of these sources shall be discussed.

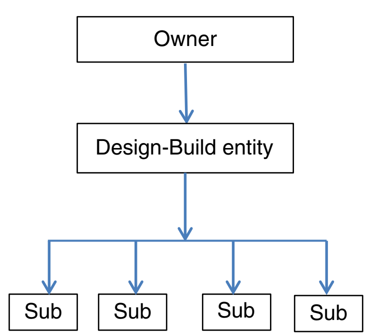

Figure 12.1 Contractual Relationships Between Parties in Design Build.

Literature Review

The literature contains many classic works dealing with the characteristics of the DB delivery system. In one of these, Songer and Molenaar (1996) argued that, 'if used correctly, DB promotes constructability and innovation in the same manner as a VE plan'.

Almost all US state transportation agencies utilise a concept called *value engineering* (VE), an initiative with the sole expressed purpose of using innovation and creativity to improve the value of the project. Some agencies employ a VE program through which teams conduct studies prior to procurement to seek opportunities to increase value by either obtaining higher quality for a comparable price or comparable quality for a lower price. The deliverable from such studies is a VE plan that typically outlines one or more innovative ways to accomplish the goal. Other agencies utilise post-award VE by writing it into their construction contracts, allowing a contractor to submit a VE change proposal identifying an innovation opportunity that can result in savings for the transportation agency and, hopefully, the contractor.

By their statement, Songer and Molenaar (1996) assert the state transportation agencies' use of DB offers innovation as an additional advantage beyond simply a faster project delivery time: not in a small or incremental way, but with an impact as significant as that of VE, an often tedious and time-consuming initiative. Their statement leads to a hypothesis that DB encourages innovation to such an extent as to equal a VE program.

Recently, the Transportation Research Board and the American Association of State Highway and Transportation Officials commissioned a research study on the design process of DB and CMGC (Minchin et al. 2013). Linking VE to innovation, the report discusses how state transportation agencies with the most successful DB programs handle the innovations offered by DB teams in the pre-award phase. These innovations are typically expressed via cost-saving alternative technical concepts submitted with teams' proposals. This mechanism for innovation offers agencies the opportunity to benefit from all proposers' alternative technical concepts: If the state transportation agency offers a compensatory stipend to unsuccessful proposers, a condition of their acceptance of the money is their assignment of their alternative technical concepts' intellectual property rights to the state transportation agency for sharing with the successful proposer and potential incorporation into the project (Minchin et al. 2013).

The report also discussed innovations introduced post-award, concluding:

> *Although it is more beneficial for the agency to include innovations prior to contract award, the agency should encourage the design-builder to propose innovations after contract award, support these efforts, and be willing to share the cost savings.*

Finally, the study's final report links VE to innovation but frames these as separate topics. The report urges the owner to write the request for proposal to encourage innovation (Minchin et al. 2013).

Innovations in specific areas and specialties are also facilitated by using DB. Gransberg et al. (1999) state that '[DB] should be used when … innovative environmental protection is inherent to the successful execution of the project'. Riley, Diller and Kerr (2005) argue that mechanical contractors 'are often willing to adopt new technologies and innovative solutions' when involved in a DB contract, and that the early involvement of the mechanical contractor in the DB process 'allows more opportunities for innovative cost reducing ideas, such as.… the adaptive re-use of existing systems to be introduced and estimated'. Yates (1995) stated that the use of the DB approach

> *directly affects factors most likely to influence competitiveness, including the capacity to adapt new technologies to stay abreast of the competition. These include a trend towards automation within the industry.*

Empirical Investigation

As part of an investigation into how US agencies handle the design portion of DB, interviews were conducted with individuals inside and outside several agencies with experience on DB projects funded and executed by these state transportation agencies. A visit to the North Carolina Department of Transportation (NCDOT) offered particular insights into the nature of innovation in DB contracting.

The interviewed individuals in the department identified numerous instances of innovation that had saved substantial time and money. Significantly, one engineer commented that he and other designers could design DBB projects with as much innovation as private sector engineers design their DB projects, except for two elements. One was that the engineers lacked the advantage of the contractor's practical knowledge (1) of the best way to build a project and (2) whether it could be built the way it was designed. But the main element that gave DB teams' engineers such an advantage over the department's DBB design team was that each contractor has personnel with specialized knowledge, skills and capabilities, and each contractor also has a particular set of equipment, implements and materials sources. Therefore, each DB team can generate a design that best utilises the unique abilities of the contractor who will perform the work. If the state's DBB design team optimized its design for a specific skill set or equipment fleet, contractors that did not possess the ability to prosecute the work that way would see themselves as at a competitive disadvantage and potentially file legal claims against the NCDOT, contending that the department was favouring the contractor(s) that possessed the personnel and equipment to build the project the way it was designed. Therefore, the design team must produce designs that can be built with relatively equal efficiency in any number of ways, satisfying 'the lowest common denominator' (Minchin, 2012).

One criterion that the NCDOT uses to select DB projects is the opportunity for innovation. Depending on the project, the weight assigned to the innovation criteria varies, but typically ranges between 5–10% of the score. Additionally, the technical quality parameter for determining the 'best value' DB team is also influenced by a project's opportunity for innovation. For example, complex projects that offer extensive opportunity for innovation typically have a maximum quality credit percentage between 25–30%, whereas projects with little flexibility typically have a percentage of 15% or lower. Furthermore, DB projects with limited opportunity for innovation and a narrow scope of work are procured as express DB projects that do not require a technical proposal submittal. The following are three examples of innovations from the use of DB on NCDOT highway construction.

I-40 Widening – Wake County, North Carolina

This project widened approximately 6.2 miles of Interstate Highway 40 (I-40) in Wake County. The successful DB team received the highest overall technical score and tied for first in the innovation category, partially because of their incorporation of two conveyor belt systems to transport stone and asphalt to the I-40 median during construction. These conveyor systems eliminated approximately 237 lane closures and 11,800 truckloads entering/exiting the median. The project cost savings resulting from the incorporation of these conveyor systems was approximately US$1.5 million from higher stone and asphalt production, lower hauling costs, reduced lane closure costs, lower supervision requirements and a shorter construction schedule. Reducing the lane closures and hauling trips also improved safety through the construction zone for the travelling public, as well as the DB team.

I-85 Widening – Cabarrus County, North Carolina

A second project widened approximately 6.8 miles of I-85 in Cabarrus County. All widening was performed in the median. The DB team proposed a temporary access bridge and ramp that allowed material, equipment and personnel to be transported to the median and northbound shoulder with no impact to the highway, minimising hauling on public roads. This innovative access arrangement eliminated approximately 550 lane closures and 16,500 truckloads of material from being hauled on I-85. It also allowed haul vehicles, crew vehicles and NCDOT personnel to have safe unrestricted access to the median at any time of day. The cost savings resulting from the incorporation of the median access bridge was approximately US$5 million as the result of higher production, greater efficiency and increased flexibility. As in the other projects, this innovation also improved construction-zone safety.

I-85 / I-485 Interchange – Mecklenburg County, North Carolina

This project constructed a new interchange between I-85 and I-485 in Mecklenburg County. The DB team was awarded the job partially because of its innovative conversion of a four-level stacked interchange to a two-level turbine interchange, which eliminated approximately 2 million cubic yards of borrow and a highway detour that would have been required to set steel girders during construction of a four-level interchange. The turbine interchange lowered the roadway embankment heights by approximately 40 feet, minimising potential lane closures during icy conditions that might be required for a four-level interchange. The cost savings resulting from the turbine-interchange concept was approximately US$30 million. Additionally, whereas the turbine interchange increased the number of bridges approximately threefold, these structures were considerably smaller and simpler, thus reducing future maintenance and widening costs.

Conclusion

The conclusion following from this research into the effects of DB on innovation is quite clear-cut: Our findings support the conclusion drawn by Songer and Molenaar (1996) that 'if used correctly, DB promotes constructability and innovation in the same manner as a VE plan'.

Public-Private Partnerships

System Description

Prior to any discussion of public-private partnerships (PPPs), some clarification of terminology is necessary, because the term spans a wide range of contracting approaches and has no single agreed definition. Proposed definitions range from very broad categorizations such as that issued by the US Department of Transportation (2004), which even includes DB projects—

> *A public-private partnership is a contractual agreement formed between public and private sector partners, which allows more private sector participation than is traditional.*

—to more focussed definitions from the academic literature, such as that offered by Leiringer (2006):

> *A public-private partnership is an arrangement between public sector and private sector investors and businesses whereby the private sector on a non-recourse or limited-recourse financial basis provides a service under a concession for a defined period that would otherwise be provided by the public sector.*

This narrower definition is used in the following discussion, with particular focus on PPP that involve new construction. For these, additional terminology is often used to designate specific forms of PPP contractual arrangements (e.g. build-operate-transfer, BOT; build-own-operate-transfer, BOOT; design-build-finance-operate, DBFO; and design-build-finance-operate-maintain, DBFOM). These terms also lack fixed definitions, however, and their usage varies regionally: international comparisons have shown that 'one man's BOOT is another's DBFO' (US Department of Transportation 2009).

Even so, as these acronyms indicate, the DB concept is closely interwoven with PPP delivery, enabling many DB innovation mechanisms to be realised in PPPs as well. Indeed, nearly every PPP that involves construction has a DB project at its core while integrating the additional private sector functions of finance (initiated prior to the DB contract award) and operations/maintenance (initiated after completion of the DB works). Figure 12.2 presents a simplified conceptual diagram of this integration of DB into the PPP setting. The concessionaire (sometimes also termed *developer* or *special-purpose vehicle*) is the agent delivering the two primary functions that differentiate DBs from PPPs, namely: arranging for project financing, typically through a combination of equity and debt; and contracting with an operations/maintenance provider to preserve the facility's serviceability throughout the duration of the concession term.

The consideration of PPPs in a chapter on US transportation project delivery is fitting, because PPP contracting in this country to date has been focussed almost entirely on highway facilities. Despite the extensive global use of this delivery approach for social infrastructure and non-highway transportation facilities, PPPs in these sectors are still in their very early stages in the US.

In addition, of all the sectors that use PPPs around the world, transportation is by far the largest, with its 2012 global deal flow of some US$35 billion exceeding that year's contract values of all other PPP sectors combined

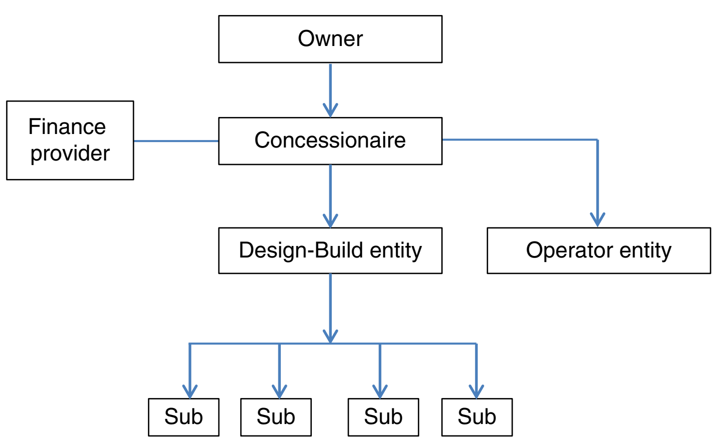

Figure 12.2 Contractual Relationships Among Parties in Private Public Partnerships.

(water, energy, social, defense and telecommunications). And within the transportation sector (which includes roads, rail, ports, airports and related infrastructure), road projects represent by a wide margin the largest segment of this sector globally (Mahmudova 2013).

Discussion

One key research contribution on this topic is Leiringer's (2006) assessment probing the actual role of PPPs' influence on innovation, focussing particularly on technological innovations in the design and construction phases of PPP projects. That review identified four drivers by which such innovation had been claimed in previous research: (1) increased collaborative working, (2) greater design freedom, (3) more efficient risk transfer and (4) longer-term commitment. Through empirical study of PPP projects, Leiringer called into question the correlation between these four mechanisms and actual improvements in innovation, a hypothesis that we consider here further in light of subsequent developments in research and practice.

Other research on the extent of innovation in PPPs generally agrees with Leiringer's position. By examining four case studies in the highway, education, defense and prison sectors, Eaton, Akbiyikli and Dickinson (2006) concluded that practical impediments, however unintentional, effectively stifle innovation in PPP projects. Rangel and Galende (2010), who conducted a quantitative assessment of PPP innovation drivers in 68 Spanish highway concessions, found that these drivers fostered growth in bidders' research and development activities but did not otherwise meaningfully increase the level of innovation. And instead of focussing on independent drivers, Gross and Garvin (2011) asserted that the effectiveness of PPP contractual mechanisms in achieving beneficial outcomes results from drivers' joint interactions rather than their discrete influences. Even so, consideration of Leiringer's four innovation mechanisms individually through the lens of practice can help shed light on the apparent disconnect between PPP innovation goals and reality. These issues are explored next, under the headings Design Freedom, Collaborative Working, Risk Transfer and Long-Term Commitment.

Design Freedom

Leiringer (2006) posited that PPPs' typical use of performance-based specifications with the public sector's concomitant invitation to design creativity encountered sufficient hurdles to preclude significant design innovation, and his research findings generally align with this thesis. Yet the element of increased design freedom is among the aspects that PPP share in common with DB projects—and the achievement of real innovation in this area was conclusively shown in the preceding section.

Why is there a difference in these conclusions? One potential explanation is the variability in risk treatment between DB-for-public-owner and DB-for-concessionaire environments. Because of the rigidity of financing structures, it is more important to concessionaires that the DB contract have a fixed cost rather than the lowest cost; hence, concessionaires are willing to accept higher contingencies in the design-builder's price in exchange for the contractor's absorption of greater risk. Public sector owners, on the other hand, are typically more prepared to serve as the insurers against low-probability but high-cost risks (such as differing site conditions or *force-majeure* impacts) that would increase the DB contract price, in exchange for a lower up-front cost than if the contractor bore these risks from the outset.

Hence, it can be concluded that even though design-builders in PPP and non-PPP environments nominally enjoy the same amount of design freedom, the greater the downside for PPP design-builders (in the form of less compensation for risk taking) induces them to avoid risks even at the cost of reduced innovation, a perspective that unifies the findings of Minchin's (2012) and Leiringer's (2006) research.

Collaborative Working

As with the element of design freedom, the potential innovation benefits of collaborative working stem largely from the DB core of a PPP project. Although Minchin et al. (2013) link collaborative contract mechanisms such as VE and alternative technical concepts with successful technological innovation in DB projects, Leiringer's conclusions (2006) about collaborative working are less favourable for PPPs. Hence, it must again be concluded that some element in the PPP structure mutes the innovation benefits that can exist in its DB core.

Exploring the ability of collaborative working to facilitate innovation in PPPs, Leiringer (2006) points to 'the stringent fashion in which the contracts…are written in PPPs', noting 'the manner in which they are formulated make it very difficult for the contractor to make changes as the project develops'. These limitations inevitably reduce the benefits of VE and alternative technical concept-based innovation and help explain the challenge of transferring a beneficial DB structure to achieve similar success in the PPP setting.

Risk Transfer

Although certain elements of construction-related risk transfer were highlighted in the preceding consideration of design freedom, the PPP-specific aspects of risk transfer are also highly germane to understanding why these contracts have historically realised only minimal benefits from innovation. Among these aspects unique to PPPs are the risk-transfer mechanisms between the concessionaire and its primary counterparties: the owner, the finance providers, and the design-builder (Figure 12.2). Interestingly, far more research exists on the first relationship than on the latter two.

Of particular note from a practical standpoint, however, is lenders' influence on DB innovation. Only a small portion of the funding for PPP projects is typically drawn from the concessionaire's equity, with much or all of the remaining monies solicited from the credit markets via bonds or bank debt. Given that PPP debt offers a safer but lower return on investment than PPP equity, such lenders are traditionally averse to absorbing risk. In exploring the impact of risk on PPP borrowing costs, Blanc-Brude and Strange (2007) note that project structures divide risks 'into those that are managed through contractual allocations among different stakeholders, and those that remain unmanaged and are thus priced' into the cost of capital.

Because PPP concessionaires benefit from efficient financing as well as from efficient construction and operations, they seek to minimise these unmanaged risks that increase the cost of borrowing. In the authors' experience, one metric by which lenders assess the management of project risks is the extent to which the proposed design and construction methods are proven and familiar. A design-builder who offers an innovative construction approach, regardless of how promising and efficient, will give the lenders less comfort than one who proposes a traditional, even if somewhat more costly, solution.

This pressure, which is communicated from the concessionaire to the design-builder, also exercises a damper on design and construction innovation in PPPs. On this topic, whereas it can fruitfully be argued that financial innovation in structuring PPP transactions is extensive and well incentivised, we here restrict our focus to technological innovation, paralleling the emphasis of Leiringer's (2006) work.

Long-Term Commitment

PPP concessionaires' long-term commitment to maintain and operate their constructed facilities is another key differentiator between DB contracts performed for concessionaires and those for public owners. In the US, these operation periods generally range from 30–99 years, with the majority of PPP road concessions having a term of 50 years or more. These durations exceed the life span of many replaceable project elements, such as bridge paint coatings and highway asphalt pavements. Hence, it would seem reasonable for concessionaires to seek innovative up-front solutions from design-builders to extend the life cycle of replaceable elements and thus lengthen the interval between major maintenance expenditures.

In practice, the correlation is not convincing. Whereas PPPs may be designed and built with longer-lasting pavements or paint coatings, for instance, the mere use of higher quality materials is not necessarily a marker of innovation. Indeed, Leiringer (2006) notes that little empirical research has been performed to verify the connection between PPPs' longer term commitments and innovative solutions. But it is clear that PPP contracts nevertheless incentivise a life cycle view of design and construction, a perspective that offers more opportunities for innovation. In a non-PPP DB contract, the procurement structure typically rewards design-builders for minimising first costs and grants them little incentive, unless somehow enforced by contract, to choose methods and materials that extend a project's lifespan.

Conclusion

Based on these perspectives from research and practice, the authors would concur with Leiringer's (2006) hypothesis that the mechanisms traditionally purported to enhance technological innovation in PPPs have not been proven effective, and may in fact be largely ineffective in achieving this goal.

Construction-Manager-as-General-Contractor

System Description

Like DB, the construction-manager-as-general-contractor (CMGC) delivery system, as applied to transportation construction in most US states, is a fast-track system that permits construction to commence at any location along a proposed highway route where right-of-way and required permits have been procured and the design sufficiently completed. Under CMGC, unlike DB, the state transportation agency has a direct contractual relationship with the designer and, hence, control over the design process, a characteristic of DBB that is popular with most state transportation agencies (see Figure 12.3). Accordingly, CMGC offers much the same advantages and disadvantages as DB, except that CMGC provides the additional benefit of easier, and probably greater, innovation from the contractor, because of freedom from the administrative processes usually required for VE under the DB system. Furthermore, CMGC avoids disadvantages related to the lack of a direct contractual relationship between the state transportation agency and the designer.

Literature Review

Gransberg and Shane (2010) assert that '[CMGC] project delivery's major benefit to the agency is derived from contractor input to the preconstruction design process'. The authors' research indicates that the contractor's input

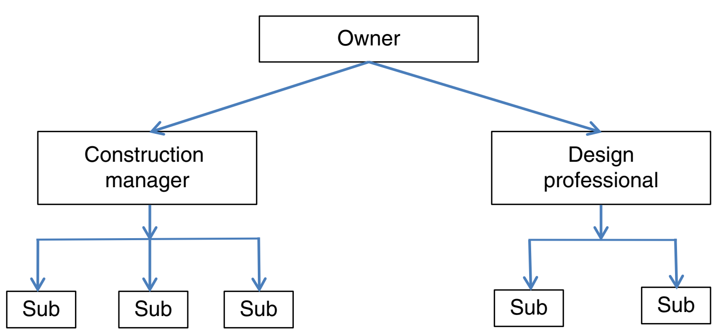

Figure 12.3 Contractual Relationships Between Parties in Construction-Manager-as-General-Contractor.

to the preconstruction design process yields three distinct, though sometimes overlapping, benefits. One is the earlier execution of third-party preconstruction activities: permitting agencies and utility companies often take the project more seriously once the contractor comes on board, generally resulting in faster issuance of permits and relocation of utility lines. Other benefits are actually the aggregation of many advantages that come under the headings 'constructability' and 'innovation' (Minchin et al. 2013).

Minchin et al. (2013) find that practitioners consider these latter two items, the advantages offered by constructability and innovation, to form a significantly greater benefit of using CMGC than the schedule advantages achieved by earlier pre-construction activities, as important as those are. The overlap here is that innovation sometimes helps with these third-party activities. More importantly, if constructability and innovation are combined under a heading 'contractor input to the preconstruction design process', they would certainly be considered the most important benefit one would derive from utilising CMGC (Minchin et al. 2013). Therefore, there is agreement with the statement made by Gransberg and Shane (2010).

Schierholz, Gransberg and McMinimee (2012) published a list that ranked the benefits of using the CMGC delivery method. The list reflected a compiled perspective of twenty-nine experts who had ranked benefits that they or their agency considered important. This assessment ranked 'CMGC design input' in second place, behind only the 'ability to fast-track', which is offered by all fast-track systems. 'Enhanced design quality' was tied for eleventh, and 'innovation' finished thirteenth of twenty-eight, with seven respondents deeming it important. For reasons mentioned earlier, findings in Minchin et al. (2013) do not agree with these rankings, but indicate that CMGC (contractor) design input is the main reason for the enhanced design quality and that innovation by the contractor in this role is the major contribution of the design input. Actually, it would seem that innovation is the single greatest potential benefit to using CMGC (Minchin et al. 2013). So, we cannot agree with the rankings offered by Schierholz, Gransberg and McMinimee (2012). One possible reason for the discrepancy in research results, based on the opinions of experts at the time, is that the Minchin interviews were conducted at least 30 months after the majority of the Schierholz et al. data was gathered. CMGC delivery is still in its infancy and most, if not all, of the data making up the Schierholz, Gransberg and McMinimee (2012) ranking was gathered before the Federal Highway Administration's Every Day Counts initiatives were invoked and projects such as Mountain View Corridor in Utah had not been completed when much or all of these data were collected.

Schierholz (2012) performed a study subsequent to the Schierholz, Gransberg and McMinimee (2012) research, probing why twelve state transportation agencies chose CMGC for delivery of specific projects. In Schierholz's investigation, the reasons that 'get early contractor involvement', 'encourage constructability' and 'encourage innovation' were identified as the three most important factors not related to project duration. These conclusions align more closely with findings in Minchin et al. (2013).

Empirical Investigation

Utah Department of Transportation has been the leading state transportation agency in the US in the use of CMGC for highway construction. This agency has experienced success on many projects using CMGC. One of the best examples of how innovations were enabled by the use of CMGC is the Mountain View Corridor project already mentioned; it was envisioned as a 15-mile freeway in north central Utah servicing thirteen municipalities. The project was ultimately extended to 17.5 miles in length as the result of the saving of US$117 million by the innovations enacted by the contractor that in our view could not have happened under any delivery system used in the US except CMGC.

The location of the Mountain View Corridor spanned some of the highest concentration of utility lines in the US, because this is where large portions of these utility lines breach the Rocky Mountains. The contractor, wary of the risks involved with constructing a highway through these utility lines, had included substantial contingencies in its bid to account for the risk. Upon receiving the contractor's early post-award cost estimates, the Utah Department of Transportation realised it could lower those costs by assuming some of the risk that the contractor was facing. The department then instituted quarterly meetings aimed at identifying and mitigating the risks faced by the contractor.

First, the transportation department told the contractor that the department itself would assume all risks associated with utilities. This resulted in an immediate lowering of the contractor's cost estimate. Then the project team began to explore risks other than utilities, and went through the same process with those risks. In the end, a process of quarterly risk reviews that included the designers, the contractors, Utah Department of Transportation personnel, consultants and all other stakeholders as needed used a process called *Decision analysis by ranking techniques*, *risk registers, risk assignment and risk retirement* to save and set aside about US$117 million. All of this money was used to extend the contract. Table 12.1 identifies specific reinvestment of the Mountain View Corridor funds beyond originally scoped construction limits. These items were added gradually over time as risks were reduced through innovation and contingency could be reinvested.

Table 12.1 Additional Mountain View Corridor Project Scope Enabled by Innovations Resulting from Construction-Manager-as-General-Contractor Delivery.

Reinvestment	Reinvestment Amount (US$)
Golf course reconstruction	$18 m
Kern River gas relocation	18 m
Residential relocation (150 properties)	40 m
Kennecott Rail Line relocation	11 m
Rocky Mountain Power relocation	20 m
Water Tank relocation	4 m
Additional earthwork	6 m

The reinvestments turned the 15-mile project into a 17.5-mile project. All of those interviewed credited the success of the project to the CMGC delivery system's allowing contractual innovations. These included enabling the highway to be built outside the original contract limits without a change to the contract documents; the owner's assumption of progressively more risk post-award to achieve lower construction costs; and technical solutions such as those employed by the contractor to span the dense concentration of utility lines (instead of relocating them). These are all novel and creative solutions that the contractor would never have tried without the freedom provided by the owner's assuming the above-noted risks.

As another example, Gambatese and Hallowell (2011) describe a very large tunnel project built using something the authors called 'CMDB', a hybrid of DB and CMGC, in which the tunnel wall was specified to be held back by wood, nail boards and face plates. However, the soil to be held back was very wet and highly organic. As a result, it did not hold up well and the original tunnel wall design had to be scrapped. The contractor implemented ground freezing to stabilize the soil with refrigerated coolant circulated through subsurface pipes. The innovative aspect was related to the scale of the operation and was facilitated by the CMDB delivery system: This technique had previously been performed on a very small scale, but never on a structure approaching this magnitude. Also, the aspects of CMDB that facilitated the innovation are present in CMGC.

Discussion

The key aspects of delivery systems impacting innovation practices are related to the degree that they give designers and constructors the freedom, flexibility and resources necessary to innovate. Some delivery systems would seem to actively incentivise innovation, whereas others hinder it. Blayse and Manley (2004) argue that 'construction firms need to innovate to win projects and to improve the financial results of these projects'; that is, they must innovate to compete. It was argued in chapter 11 that demanding customers play an extremely important role in creating a demand for innovative solutions. When clients function in this way, development and effective use of new technology can provide indispensable competitive advantages for construction firms. This necessity to innovate will result in creative problem solving and invention, which, if applied across projects and over time, becomes part of established practices, representing innovation (Slaughter 1998; Gambatese and Hallowell 2011; see also the discussion regarding the definition of innovation in chapters 1 and 2 of the present volume.)

Before the necessity for invention can meet the opportunity to apply it, the resources needed to invent must be present. The preconstruction phase of the DB and CMGC delivery systems involve the two resources necessary for invention: freedom/flexibility to invent and the skilled personnel of the contractor. In both delivery systems, the contractor is present during design and forms an integral part of the design team. The point was made succinctly by the NCDOT in-house designer, who said he and other designers could design DBB projects with as much innovation as these designers had designed their DB projects, except for two elements: These elements were the knowledge brought by the contractor and the freedom and flexibility to be innovative in their design. The research reported in the present chapter indicates that CMGC and DB both supply the necessity for invention, the flexibility, freedom and resources for invention and the flexibility and freedom for subsequent application.

Conclusion

In this chapter, we have assessed the level to which three innovative fast-track delivery systems – DB, PPP, CMGC – encourage project stakeholders to implement innovation into the design and construction of transportation construction projects in the US. Arguments concerning positions taken in published articles by prominent construction researchers related to the subject were presented. Songer and Molenaar (1996) argued that, '*if used correctly, DB promotes constructability and innovation in the same manner as a VE plan*'. Proponents of PPPs have forwarded a number of mechanisms through which PPPs promote innovation. However, Leiringer (2006) contended that the correlation between four of these issues and actual innovation increases is not so clear. Arguing the case for CMGC was more challenging, because it is in its infancy and little research has been done on the subject. We could find no direct contention in the literature related to CMGC's encouragement of innovation. Regarding DB delivery, we fully agree with the innovation perspective advanced by Songer and Molenaar. As for Leiringer's contentions regarding limited technological innovations in PPPs to date and the inconclusive effects of purported innovation drivers, we also conclude from an assessment of subsequent research and practice that these concerns are well founded. Finally, the authors agree with Gransberg and Shane's (2010) assertion that '[CMGC] project delivery's major benefit to the agency is derived from contractor input to the preconstruction design process'. Findings in Minchin et al. (2013) do not comport with the findings of Schierholz, Gransberg and McMinimee (2012) that ranked 'innovation' as only a marginally significant benefit of using the CMGC delivery method. We are somewhat more comfortable with the assertions in a second study (Schierholz 2012) that ranked innovation as the third-most important CMGC feature not related to duration, but the conclusion in Minchin et al. (2013) is that innovation actually is the most valuable feature offered by CMGC.

In summary, a review of recent literature and practice concludes that DB and CMGC strongly encourage project stakeholders in their respective processes to innovate for the improvement of the final product, whereas the incentives for innovation in PPPs are muted. We find clear indications that the relatively new CMGC delivery system offers a freedom to innovate unrivalled by other systems, including those depending on VE procedures to encourage or provide innovation.

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13

The Leitmotif of Building-Products Innovation in Finland: From Commercial Technology Exploitation to Sustainable Development

Heli Koukkari and Finn Orstavik

Introduction

The built environment is created in complex projects on and off building sites. Before built objects can be assembled, maintained or renovated, designers and builders must have access to an array of natural and human-made materials and fabricated products, often the outcome of volume production in industries with significant economies of scale. The construction products sector is manifold and large, but is generally not included in construction industry statistics, which cover on site activities of various contractors, such as the preparation of grounds, on site works and the assembly of objects. Statistics show that manufacturers supplying goods for building are found in a wide range of other industries as producers of wood, paper, mineral, metal, rubber and plastic products, machinery, electrical components and systems, automation equipment, and so on. Products are in part mass-produced standard items, but a substantial share of them are bespoke, that is, fabricated in limited numbers for particular built objects and projects.

The study of Ecorys (2011) identified the following subsectors related to the construction sector: manufacture of builders' carpentry and joinery; manufacture of bricks, tiles and construction products in baked clay; manufacture of cement, lime and plaster; manufacture of articles of concrete, plaster or cement; cutting, shaping and finishing of ornamental and building stone; and manufacture of structural metal products. Based on these statistics, the turnover of the European construction product manufacturers was estimated as €360 billion in 2009, and the number of employees was 2.6 Million (Ecorys). The study noted that several other subsectors include construction-related manufacturing, but its share could not be reliably

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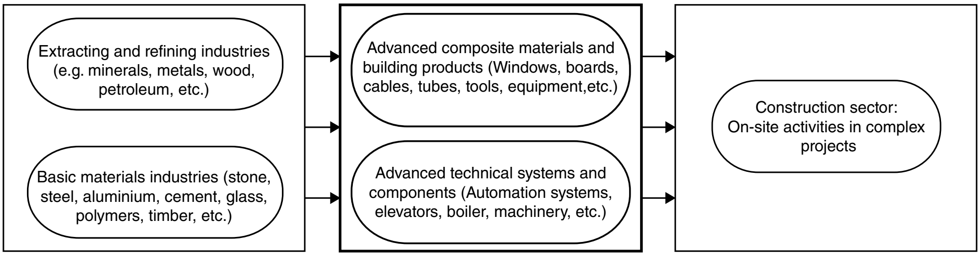

Figure 13.1 The intermediary position of the building products industry in the value chain.

distinguished. The Construction Product Regulation (CPR) of the European Union (EU) offers another approach to define a construction product as follows (CPR 2011): It is used in a permanent manner in end products of construction activities, in *works* such as buildings. Most of these products have to be CE-marked on the EU market. In general, the construction products industry can be seen as an intermediary, located between a number of basic manufacturing industries and the construction sector more narrowly defined (Figure 13.1).

In the literature on innovation in construction, the product manufacturers are identified as a related sector and the differences in operational models and innovation activities between contractors and manufacturers were recognized for example by Carassus (2004). The point has been made that construction is both oriented towards complex systems production and that production organisation is project-based, both of which have significant consequences for the way innovation processes are unfolding in the sector (e.g. Winch, 2006, Gann and Salter, 2000). What, then, can be said about building product innovation? The impact construction products have on building costs (Larsson et al. 2006), productivity (Goodrum et al. 2009; Jarkas 2010), performance of a building project (Slaughter 2000), performance of a completed building (Henderieckx et al. 2002) and environment (Sand et al. 2012) are all shown to be significant. Furthermore, researchers have concluded that most construction innovations originate from material and component manufacturers whose overall R&D investments are the largest in the broad real estate and construction sector (Pajakkala et al. 1992; Gann 1997; Koskela and Vrijhoef 1999; Pries and Dorée 2005; Manley 2008 and Ozorhon et al. 2010). Furthermore, radical innovations are more likely in this part of the broad sector than in others. However, most product innovation in construction is excluded from the construction industry analyses (Winch 2003). Except for a few contributions, for example those by Hansen (2006), Slaughter (1993, 2000) and more recently Orstavik (2014), the literature on innovation in the construction product industry is limited.

This chapter explores how manufacturers have perceived the innovation context in Finland since the 1960s when many modern construction technologies started to emerge. The analysis is based on qualitative data from a project concerning innovation context and processes of building product manufacturers, which has been recently carried out and reported by the lead author (Koukkari 2013). In Finland's national economy, 66% of investments are made in the construction sector, and its share in employment is 15% (including services for building design, property management and product manufacturing). The amount of person-years in the manufacturing industry in 2012 was 80,000 and 145,000 in the on site activities in the same year (RT 2013).

The empirical research discussed in this chapter comprises a case study in which firms' strategies in product development and on the level of corporate communications and marketing were analysed in some detail. The primary data was gathered through interviews with representatives of manufacturers, associations and research organisations. The background literature consisted of histories, biographies, technical documents and documents published by governmental and industrial organisations. The companies were selected through a process aiming to identify the leading innovators with impacts on the construction sector beyond their own portfolio. The selection procedure included interviews of representatives of industrial associations, a literature survey especially on evaluation reports of the programmes of the Finnish funding agency for innovation (TEKES) showing involved companies and their activities and data mining in the customer and publication registers of the research centre showing key players promoting product and construction innovations. From the product portfolios, a specific product innovation was selected for closer scrutiny based on the environmental marketing arguments. The innovations were studied in detail in order to find whether they had been developed in order to improve the environmental performance and to what extent marketing had been updated with environmental aspects.

Environmental issues emerged as key issues in the strategic work of international, national and regional organisations in the field of building and construction during the 1990s. The First International Conference on Sustainable Construction was held in Tampa in 1994 and introduced the following definition of *sustainable construction:* 'the creation and responsible maintenance of a healthy built environment based on resource efficient and ecological principles' (Bourdeau 1999). The International Council for Research and Innovation in Building and Construction (CIB) published its *Agenda 21 on Sustainable Construction* with other major international organisations in 1999 (CIB 1999). Today, sustainability principles are gradually being implemented as voluntary standards, assessment methods, rating systems and software that support the design of buildings. In part as a consequence of increasing knowledge about environmental impacts over the life cycle of buildings, more attention has been paid also to construction products.

For the current analysis, the data was used to trace the environmental objectives. Importantly, available data allowed in-depth analysis of what the actual innovation drivers and product development strategies amounted to in the respective firms and therefore served to identify a possible mismatch between marketing strategies and actual product innovation. The data here is from Finland, but the trend described in the preceding paragraph has international resonance and affects both policymaking and construction research. A study requested by the European Parliament's Committee on Industry, Research and Energy about eco-innovation emphasised the importance of manufacturing and materials:

> When considering the impact eco-innovation can have on resource or energy efficiency, the most gains are to be made when tackling the 'upstream' or production part of the supply chain (ITRE 2009).

An essential part of the political and regulatory efforts have been directed towards the energy efficiency of buildings. (See also the related discussion about micro-generation technology in chapter 6 in this volume.) So far, most efforts have been made in improving and modifying existing solutions and processes. This is in line with conclusions of the Intergovernmental Panel on Climate Change (IPCC) survey from 2007. This survey concludes that there is a broad array of accessible and cost-effective technologies and know-how to reduce energy losses during the operation of buildings available today (IPCC 2007), but that there in the longer term will be need for further technological and material innovation, such as those proposed in technology roadmaps prepared by the staff of the European Commission (European Commission 2011) and the International Energy Agency (OECD/IEA 2013).

The broad context of innovation in construction products was shaped by the significant political attention being paid to global environmental and climate challenges and the need to reduce the huge environmental footprints of the construction sector with its energy uses, emissions of CO_2, use of chemical substances, and so on. The context has been impacted in a significant way by policies formulated on the level of government to address the environmental sustainability challenges. However, the context for building products innovation in Finland has also been influenced over many years by the ambition to connect scientific and industrial research to the processes of development in the construction sector as a whole, the construction products sector in particular. The key issue that will be discussed in this chapter, then, is how these two different kinds of forces originating largely in societal level policy with industry's own interest in profiting from product innovation have together shaped innovation activities in building products.

The Evolving Context of Building Products Innovation in Finland

Etzkowitz and Leydesdorff have in a number of books and articles (e.g. Etzkowitz and Leydesdorff 1997 and 2000) developed the so-called Triple Helix model of innovation. This model formulates a systemic perspective on innovation in which the active interplay of three main sectors (industry, university and government) is fundamental for all innovation processes and for the overall functioning of diverse kinds of innovation systems. Reflecting Mytelka's and Smith's (2002) idea of a circularity of policy learning and scientific learning, the Finnish policy framework has been inspired by innovation theory at the same time that Finnish policy action and outcomes have given new data and other inputs into the further elaboration of innovation theory.

The trilateral interaction between government, research organisations and industries has been a working model in several fields for decades in Finland. This holds also for the development of the national strategy for sustainable development (OECD 2006). The national strategies influencing primarily directions of construction innovation are presented by the Ministry of Employment and the Economy and the Ministry of the Environment. Their strategies and action plans are typically prepared through a communication process with industrial associations and other stakeholders.

The Ministry of Employment and the Economy has a central role in shaping the innovation strategies for the country. The Centre of Technology and Innovations TEKES is governed by the ministry, and it is been the main funding organisation of joint technology research projects since 1983. The centre started to co-ordinate industrywide technology programmes during the beginning of the 1990s. These were materials oriented, with efforts being made in development of concrete (in 1992–1996), steel (in 1995–2000) and wood (in 1996–1998). To mention but one example that is related to the theme of the present chapter, the programme Environmental Technology in Construction facilitated the globally pioneering role of the Finnish polyurethane industry in abandoning chloroflurocarbon (CFC) compounds in the years in 1994–1999 (TEKES 2000). In the late 1990s, technology programmes were repositioned, and were basically seen as instruments promoting cluster formation (TEKES 2003). The resulting strategy for the real estate and construction cluster development was carried out through five technology programs during the years 1997–2007. The objective was to launch and reinforce R&D and innovation activities, to increase the size of the technology programs and to promote company-driven R&D activities. According to the evaluation report, development of software and services was prioritised more than development of tangible construction products (TEKES 2009). However, the TEKES programmes of the period were clearly more generic than later programmes, such as the recent Sustainable Communities programme (2007–2012) which was created to generate business activities in the design, construction and maintenance of sustainable and energy efficient buildings.

The Ministry for Employment and the Economy also initiated a preparation of new types of public-private organisations for strategic R&D. The company RYM Oy was founded in 2009 as the Strategic Centre for Science, Technology and Innovation of the Built Environment. RYM has 53 owners (shareholders) today, among which nine are product manufacturers and seven are research organisations; the remainder includes, for example, developers, contractors, consultants and regional councils (cities). The main thematic fields covered by the organisation are energy efficiency, construction operating models and processes, competitive built environment infrastructure, and user-oriented built environment spaces. In line with the innovation policy guidelines published by the Ministry of Economy and Environment (TEM 2009), funding is made available to large R&D programmes coordinated by the strategic centres.

Finland was among forerunners in research and development of methods to assess environmental impacts of construction products and buildings and to promote ecological solutions. Since the middle of the 1990s, publicly supported R&D programmes have been organised, such as the Ecological Construction of the Academy of Finland in 1995–2002 (FA 2002), the Environmental Cluster Research Programme of several ministries in 1997–2000 (TEKES 2001b; Häkkinen et al. 1999), and the Ecologically Sustainable Construction Programme of the Finnish Government in 1998–2002, which aimed to speed up the development processes, such as the experimental Viikki suburb in Helsinki (Helsinki 2005), that were already under way.

Even more importantly from the viewpoint of product manufacturers, building regulations in Finland have gradually been transformed. Regulations comprise laws and statutes of the parliament and the Building Code, which is governed by the Ministry of Environment. The Building Code was enacted in 1976 and was initially developed on the basis of more specific codes covering technical requirements regarding structural properties and fire safety, and other recommendations and rules stemming in large part from professional organisations, representing generally accepted design methods and norms in the industry. Since 1995, this Building Code has been adapted to the directives and regulations coming out of the European Union. The implementation of European law, such as the *Construction Product Directive* (CPD) and the subsequent *Construction Product Regulation* (2011), the ten Eurocode standards (EN1990–EN1999) for the design of buildings and other civil engineering works and construction products, the *Energy Performance of Buildings Directive* (EPBD) in 2002 and its sequel (EPBD 2010), have caused major changes in the national regulation in Finland.

The CPR and EPBD are regulatory mechanisms through which the environmental and sustainability strategies of the European Union are realised and which set requirements to construction products. They constitute mechanisms that establish a framework for construction product innovation that are very far from being only political rhetoric. Thus, the shift of the innovation policy discourse has undoubtedly been accompanied by tangible and consequential changes in the framework that single firms and the industry as a whole must deal with and adapt to.

The Evolution of Industry Strategies

By considering the facts about the evolution of the context for innovation in building products in Finland as presented in the previous section, it is obvious that there has been a shift of focus in Finnish innovation policy for construction. Furthermore, it would seem that this has created a shift in the orientation of the system of research and development connected to industry. There are indications of a turn away from technology-based materials and product innovation, towards environmental (or ‘green’) innovation. Another way to say this is that there has been a change in orientation from a technology push towards a demand-oriented strategy serving to address issues facing stakeholders in the built environment, and then in a particular way, issues related to sustainability.

Earlier research focussing on the innovation activities of the Finnish building product manufacturers (Koukkari, 2013) has shown that policy initiatives, public resources and joint efforts have been important, and have affected actors on the meso level, specifically organisations of the real estate and construction sector, not least the Confederation of Finnish Construction Industries RT (CFCI). This umbrella organisation has a number of member organisations involving about 2,700 different companies. RT is an important lobbying organisation for these employers. Its member organisation of construction product manufacturers (Rakennus tuoteteollisuus RTT ry) involves 130 companies.

The construction product manufacturers belong to various associations organised typically around basic load-bearing materials such as concrete, steel, and wood and plastics. All these associations take upon themselves to act as initiators, brokers and co-ordinators of R&D activities relevant for their particular member firms. The RT and the associations have jointly funded several co-ordinated programmes and projects. RT also has had a leading role in preparing for the strategic research agenda of RYM, mentioned earlier.

During the first decade of the new millennium, the industry clearly embraced the cluster thinking and embarked on several efforts to develop strategic relationships among all the stakeholders of the real estate and construction sector and the research community. This is shown, for example, by the fact that the confederation-coordinated preparation of the sectorwide effort Vision 2010: Fundaments for a Good Life. The report on The Built Environment 2025 was published as a sequel to the Fundaments for a Good Life effort in 2010 by the Kira Forum, a cooperation group of thirteen national organisations involving RT, trade associations such as those of architects, design consultants, property owners and service providers, and Finnish Association of Civil Engineers (RIL). According to this group, future manufactured products for building would be made so that (KiRa 2011)

> the material-efficiency is taken care of; materials are easy to maintain and change; the production cause as little emissions as possible; the design considers life cycles of all the materials and products; and waste is used in energy production (KiRa 2011).

It is quite clear that the policy change at the government level did have an impact on the industry's leading employer organisations. RT proclaimed its official views about sustainable construction and energy efficiency in two brochures in 2010 (RT 2010a, 2010b); the confederation had supported R&D on methods of eco-efficient and sustainable construction products and buildings since the 1990s (TEKES 2000). The confederation has been represented in several working groups of the Ministry of Environment in issues, such as resource efficiency, and most recently, has started a joint project on zero-energy buildings (RT 2014).

Innovation Strategies in the Finnish Building Products Industry

Policy and actions changed at the level of national policy and at an organisational level. What, then, about the firms in the building products industry? Did their innovation strategies change as well? Looking some decades back, it is clear that prefabricated concrete construction has been in the mainstream of building technology in Finland since the 1970s related to high demand for housing and trends in the overall Finnish economy. Steel-based construction was developed in particular in the 1990s and 2000s, but the technology has not managed to win the main markets of office and residential building. Wood-based construction has also been developed, but has been competitive only in the small house-building sector, at least until recent years when it has become relevant in the context of sustainable building (TEM 2013). Information technology-assisted building and design has been a key R&D focus since the mid-1980s (Björk 2009; TEKES 2009).

This general picture is of a situation in which product innovations were largely technology and market driven. Major changes in the innovation context were caused by the internationalisation of companies since the late 1980s and Finland's entrance into the European Union in 1995. Furthermore, the cement, concrete and steel industries were completely reorganised in the beginning of the 1990s because of a recession triggered by the demise of the Soviet Union. Companies reduced investments in R&D, but building material-oriented technology programmes were sustained through these years of dramatic changes (TEKES 2009). The first European joint projects also started at this time and was important especially for the steel construction sector.

Some of the involved companies are among those studied by Koukkari (2013) and were quite different in terms of size, turnover and product portfolios. Four of the companies (Parma, Consolis, Rautaruukki and MetsäWood) are leading manufacturers on the domestic market in their specific technology fields today, and they have had a leading role in TEKES's long-running industrial R&D programmes related to concrete, steel, and wood construction technologies. Today, these firms are involved in RYM activities and a similar centre dedicated to the forest sector (the Finnish Bioeconomy Cluster [FIBIC]). Data about the innovation activities of these firms span about 40 years. Two other companies (Paroc and Peikko) have had significant success internationally over a period of about 30 years based on continuing product innovation.

All of the companies studied and the selected product innovation for each of them are listed in Table 13.1. Two of the firms, Parma and Rudus, manufacture concrete or concrete-based products, and their preceding large-scale companies were the leading manufacturers in the transition to prefabricated concrete construction. The new technology achieved a 60% share of the residential construction market by the end of 1970s and 70% by the end of 1980s (SBK 2009). Parma is the leading domestic manufacturer today in Finland. Rudus pioneered the production of ready-mixed

Table 13.1 Information about the companies in 2013 and innovation cases studied regarding environmental objectives in building product innovation.

Case company and - its current product portfolio	Year of establishing[1]	Data in 2013			Member in RT/RTT	Shareholder of RYM
		Turnover M Euros	Position[3]	Personnel		
Parma, belongs to the international Consolis - Prefabricated concrete and multi-material components	1993	145.6	16	714	RTT	yes
Rudus, belongs to the international CRH - Customised concretes, recycling of concrete	1999	378.0	10	1155	RTT	yes
Peikko, an internationally operating Finnish company - Connecting products for concrete construction, products for composite construction	1965	126.0	20	1058	RTT	no
Ruukki Construction, belongs to an internationally operating Rautaruukki (to be merged with the Swedish SSAB this year) - Steel and thin-gauge steel structures, solutions for roofings, facades, sandwich panels, building concepts	1960	722.0	5	3093	RTT	yes
Paroc, internationally operating Finnish company - Stonewool insulations, sandwich panels with stone wool core	1980	433.1	9	2059	RTT	yes
Ekovilla, internationally operating Finnish company - Loose or panel products for thermal insulation from wood fibers, recycled paper as raw material	1979	20.5	47	52	RTT	no
Neapo, Finnish company operating in Finland - Modular components for residential and office buildings, extension floors, bathrooms and elevator shaft; fully equipped and complete; service provider	2006 (- 2013)	5.1[2]	-	10[2]	-	no

(*Continued*)

Table 13.1 (*Cont'd*)

Case company and - its current product portfolio	Year of establishing[1]	Data in 2013			Member in RT/RTT	Shareholder of RYM
		Turnover M Euros	Position[3]	Personnel		
Reponen, Finnish company operating in Finland - Contractor for concrete and wooden multi-storey residential buildings and owner of a manufacturer of concrete components	1952	24.0	37[4]	82	RT	no
MetsäWood, a part of internationally operating MetsäGroup - LVL (laminated veneer lumber), gluelam, wooden boards, structural system solutions	1934	897	4	2490	RTT	no[5]
SPU, internationally operating Finnish company - Polyurethane insulation products with improved fire resistance, customised solutions, building concepts	1977	24.3	45	67	RTT	yes

[1] The year of establishing refers to the current business model.
[2] Data is from the year 2012.
[3] Position refers to the position among the biggest building product manufacturers in Finland based on the turn-over (Rakennuslehti 2014).
[4] The position among the biggest contractors in Finland.
[5] MetsäWood belongs to FIBIC that is the centre of the forest sector.

concrete in Finland and is still its leading producer. Ruukki Construction produces a wide variety of steel-based products, and its role in the rise of the steel construction sector was decisive in the 1980s and 1990s in the FinnSteel Programme (Gustafsson 2010, TEKES 2001a). The company recently signed a contract for joint research with two different research organisations worth €2.5 million for the years 2014–2017. MetsäWood is a large international manufacturer of various engineered wood products, including laminated veneer lumber. Peikko manufactures steel parts for composite structures and connectors to concrete structures. Paroc produces mineral wool insulation products and sandwich panels with a wool core; Ekovilla produces insulation products from wood fibre and recycled paper. Neapo fabricates steel-based 3-D modules for multi-story buildings, and Reponen is a contractor of multi-story residential buildings. SPU produces innovative, fire resistant insulation products based on polyurethane. This manufacturer's R&D investments amount to about 4% of turnover. All these product manufacturers except Neapo have international operations and trade.

The main findings from the case study regarding the innovation drivers as experienced in these firms are presented in Table 13.2.

After considering the findings and background data, it is clear that construction product innovations have had a variety of sources and drivers. Many ideas were brought from abroad and applied to the Finnish circumstances and could be exploited because of the company's specific competences. Earlier product innovations were mostly driven by technological R&D, often in collaboration with public sector institutions. In some cases, competitive strength was improved through the use of system solutions based on software tools and automated manufacturing (CAD-CAM, robotics, and so on). An essential change in offering was the development of building concepts by both manufacturers and contractors, which influenced objectives of innovation activities of product manufacturers. As an example, Reponen's building concept was developed in cooperation with manufacturers of windows, thermal insulation and ventilation machinery; Paroc and Rautaruukki have also modified their panel wall solutions to fit with energy-efficiency requirements. Table 13.3 summarizes the selected sustainability-oriented product innovations and the context in which these specific innovations took place.

The public strategies and funding programmes were of great importance to the R&D of all the companies. The strong position of the off site concrete construction was established as a national effort involving all the stakeholders. The public funding programmes set up the rise of the steel construction, digitalisation of manufacturing, design and construction processes and methods to promote environmental and sustainability objectives. Since 1995, European governance has increasingly influenced the national governance in Finland, but tripartite working procedures have remained similar for decades in this country.

What is seen here is that that the general environmental awareness that was developed on the level of government and in the organisations also had an impact on product development and marketing efforts of key firms in the

Table 13.2 Case firms and descriptions of innovation cases with environmental content.

Company	Context and drivers of innovations in the main phases of innovation activities	Product innovation with environmental objectives and/or marketing strategy
Parma (and its predecessor)	Portfolio of prefabricated components for residential multi-storey buildings in the 1970s - fitting with the national open building system ('bookcase system') that was created through joint efforts of all the stake-holders. The activities were initiated and supported by the Ministry of Internal Affairs due to huge needs of housing. At first, tens of foreign systems were studied. The products and the national building system were adapted to offices and other types of building in the 1980s. Implementation of ICT started in the midst of 1980s. In the 1990s, the TEKES programme for the industry expanded portfolios, advanced design methods and strengthened development of BIM.	*Ecopile* is a symmetrically pre-stressed driven pile that has an improved length and capacity with less cement. The reduced weight allows more efficient transport, which also reduces embodied energy
Rudus (and its predecessor)	Basics of the industrialised on-site concrete technology were developed in the 1980s aiming at an improved competitive position against prefabrication On-site technologies were further developed through uptake of ICT in concrete plants (grading, new additivies), composite construction technologies and speeding construction processes in the 1990s; in the 2000s, the self-compacting concrete based on deep knowledge on grading of concrete and advanced chemicals was developed based on Japanese invention.	*The 'green concrete'* reduces the carbon footprint by an estimated 20–50%. It is encompass a comprehensive model of operation: Plants of ready-mixed concrete are located close to clients. A type of cement with a smaller carbon footprint is purchased. The amount of clinker is reduced through own mixing technology.
Peikko	The novel type of steel-concrete composite beam was developed at the end of 1980s at the time when the concrete industry developed own solutions for slim floors in particular for offices and the steel industry promoted composite construction in Europe. It aimed at a competitive edge in providing technical advantages and flexibility of spaces asked for by building owners; the basic product has been slightly modified in 1997due to the new automatic production line. In 2000s, a system of composite components and their connections is developed to serve the clients.	The *composite beam* allows for material savings up to 30% due to the interaction between the parts. This reduces material costs and increases usability in different designs of building spaces

Table 13.2 (*Cont'd*)

Company	Context and drivers of innovations in the main phases of innovation activities	Product innovation with environmental objectives and/or marketing strategy
Ruukki	Establishing the company in 1960 resulted in a new competitive position in the Finnish construction. The strategy initially was to offer alternatives to imported goods, but in the 1970s the focus was moved onto competing with concrete construction products. Steel-based products were developed in two lines: so called heavy structures for frames and infra and thin-gauge structures for components to be used in walls and roofs of all kinds of building. Product portfolio of structurally used thin-gauge steel was developed in the 1980s with sheets, studs and purlins. The structures were further developed to components for walls and roofs through combining with other materials and improving thermal and acoustic performance in the 1990s. ICT was adopted as a part of manufacture and technical services in the 1980s.	An *energy-efficient hall concept* based on sandwich panels with glass wool core improves thermal performance of an entire envelope in three areas: the panel, all joining details and assembling techniques. The design service was also developed including simulation software and a guarantee about the energy-efficiency. SaintGobain Isover has improved recycling content in glass wool.
Paroc	A novel type of sandwich panel was developed for light-weight construction mainly used in industrial and commercial buildings. The technology was still under development in Europe at that time. The competitive edge compared to panels with plastic core was fire safety achieved through stone wool and produced by the company itself. The product invention phase took two years and all the later product innovation phases have concerned partial modifications in materials, surface treatments, connections or use conditions.	*The sandwich panel of thickness of 300 mm* was developed to cope with energy-efficiency requirements. A new R&D field is optimization of strength and thermal properties of wool. The company's sustainability programme aims at reduction of embodied energy and CO_2.
Ekovilla	Manufacturing loose thermal insulation from recycled paper was developed in the USA and the technology was bought from there by the company. Domestic technology support was available at that time for investments that would save energy. In 2010, the company launched the insulation sheets onto markets.	*Thermal insulation made of paper waste* is marketed with environmental arguments today such as saving nature; renewable material, a small amount of embodied energy; recyclable and reusable further; material captures the CO_2 for its entire life cycle; insulation reduces energy consumption of a building.
Neapo	An off-site building concept is based on finished modules and turn-key service which was developed at the end of the 1980s by a company that delivers rooms for ships. A new company was established to elaborate a new building concept and diffuse it to the construction market. The innovation was technology based, and despite clear focus to services and user needs, the company went bankrupt.	The passive house concept based on *modular building technology* was marketed as energy-efficient 3D framing solution (thermal insulation between panel faces was at least 30 cm in walls and 50 cm in roofs). Recyclability of steel was used in marketing

(*Continued*)

Table 13.2 (*Cont'd*)

Company	Context and drivers of innovations in the main phases of innovation activities	Product innovation with environmental objectives and/or marketing strategy
	However, the company that originally developed the concept still produces the modules for buildings.	
Reponen	An energy-efficient building concept has been developed for a multi-storey residential building since 2001. The original aim was to radically reduce energy consumption but the aims are developing towards a nearly zero-energy building nowadays. The concept is realised through several solutions starting from improved energy-efficiency of the envelope. A building does not usually have a separate heating system and the small demand is taken care by ventilation. The framing structures were made of concrete in the first applications and wooden buildings have been promoted recently. LED lighting is pre-installed in some spaces such as kitchens and bathrooms. The company owns also a manufacturer of façade components.	The *concept of energy-efficient multi-storey residential* concrete building was developed as a joint effort of designers, product manufacturers and research organisations and co-ordinated by the contractor itself. A multi-storey residential building saves about 70% in energy consumption through a low-energy concept compared with current regulation.
MetsäWood	LVL products were developed through localization technology of products on the American market. The pilot plant was established in 1975. The product has not changed since 1981 when the industrial manufacturing started. Instead, a wooden building system based on manufacturers portfolio and customer service has been developed, especially in the 2000s. The lobbying with ministries has resulted to new regulation that allows use of wood for multi-story buildings in Finland.	*A multi-storey wooden building* based on LVL products is ecological and cost-efficient. Construction of a wooden multi-storey building consumes less energy and causes less CO_2 and other emissions than concrete building. In addition, structures are carbon sinks.
SPU	Polyurethane was used mostly in industrial and commercial buildings and equipment until the new energy saving objectives. The new phase started around 2000 with aiming at increasing use in residential and office buildings with an improved thermal performance compared with other insulation materials. Products were developed for various applications. Efforts were focused to improve the fire safety. Co-operation with other manufacturers and contractors has led to solutions for zero-energy multi-storey buildings.	*Ecological and fire-resistant EFR polyurethane insulation* is reusable and packed onto reusable pallets and protected with a recyclable packing hood. The company started the use of wind power in 2000. Conserving the environment for future generations is one of company's primary values.

Table 13.3 Summary of innovation characteristics and drivers.

Company	Innovation drivers and challenges in general	Innovation content	Environmental case	Innovation benefit in the case	Adoption of sustainability drivers
Parma	- Demand for rapid/low cost building - Market competition alternate supplier	- Product technology, - Technical support service	Eco-pile for fundaments	Reduced material use, reduced energy use and reduced CO_2-emission	The case was developed for environmental objectives and it is a new type of product
Rudus	- Competition with alternative products and building technology - Demand for high/special quality products	- Product technology - Service provision concept	«Green concrete»	Reduced material use, reduced energy use and reduced CO_2-emission	The case was developed for environmental objectives based on advanced technologies
Peikko	- Demand for advanced construction products and for flexibility in offices	- Steel-concrete composite products/ technologies	Composite beam for slim floors	Reduced material use, better product functionality	The case was not at first place developed for environmental objectives
Ruukki Construction	- Competition from suppliers of alternative materials/ products	- Manufacturing and product technology, building concepts and services	Low energy buildings	Reduced energy use	The case was developed for environmental objectives and it is a novel type of service and building concept
Paroc	- Value adding use of own generic insulation materials production	- Manufacturing technology - Sandwich structure	Improved sandwich panel and its connections	Reduced energy use	The case was developed for environmental objectives and it is a modification
Ekovilla	- Demand for "natural"/ low CO_2-emission products	- Use of natural materials in insulation products	Insulation product from recycled paper	Reduced energy use and reduced CO_2-emission	The case was developed for environmental objectives

(*Continued*)

Table 13.3 (*Cont'd*)

Company	Innovation drivers and challenges in general	Innovation content	Environmental case	Innovation benefit in the case	Adoption of sustainability drivers
Neapo	- Technology transition (from shipbuilding)	- Manufacturing and construction technology and design and other services	Building concept based on 3D modules	Reduced energy use	The case was not developed for environmental objectives but modified and marketed as an energy-efficient and recyclable solution
Reponen	- Demand for energy efficiency (costs)	- Contractor, design support services	Building concept	Reduced energy use	The building concept was developed for energy-efficiency
MetsäWood	- Market competition (alternative materials) - Market demand for "natural" houses - Policy support for wooden construction	- Manufacturing technology - Building technology	Building concept / design	Reduced material use, reduced energy use and reduced CO_2-emission	The case was not originally developed for environmental objectives but marketing has changed relying on wood aspects
SPU	- Demand for energy efficiency (costs) - Regulation on CFC - Regulation on fire safety	- Manufacturing technology - Material technology	Eco-efficient and fire-safe thermal insulation products	Reduced energy use	The case was developed for improved energy-efficiency

Finnish sector of building products manufacturing. The sample of firms has been important and visible in transformation of the construction sector in Finland in the past, and they still represent the innovation leaders: They represent more than half of the RYM members in the respective sector. The turn towards sustainable innovation in these firms, some large and others small, indicates a shift from focus on technology exploitation for increased profit towards an overall orientation by which the industry and its products are seen a part of an emerging sustainable economy.

Construction firms already were involved in 1999 when methods and specifications of ecological construction were published. The construction cluster was seen as an important sector for implementing national and European strategies concerning environmental and sustainability goals. National research programmes established the basis for a transformation of the innovation context, and construction firms were actively involved in and contributed to funding the development of assessment and decision-making methods related to sustainable building. Pathways to establish environmental R&D activities have been created through joint efforts of ministries, research organisations, industrial lobbying and professional and research organisations.

The Finnish construction sector was a pioneer worldwide in adopting environmental and sustainable concepts and developed new approaches while being cognisant of the broader context of the industry. The Confederation of Finnish Construction Industries already was involved in the 1990s of the sector's environmental pursuits involving major construction product manufacturers. The energy crisis in the 1970s, made saving natural resources an issue that some manufacturers observed as a new market opportunity. However, tightening regulation was a necessary push before the environmental targets became a common part of manufacturers' objectives of innovation activities. The more environment-conscious trend was absorbed into product manufacturers' marketing arguments at first, but influenced the products slowly.

True product innovations with environmental objectives emerged only during the last decade when tightening European and national regulation of buildings' energy performance became a primary driver for product innovations. Use of recycled materials, such as paper or glass waste in thermal insulation, was for some time the only example of changes. In the early marketing of products for composite construction, material savings were emphasised, but interpreted more as cost savings than an environmental value. In the case of modular building, environmental and sustainability arguments were first used only in marketing, but later used as objectives for improvements of basic solutions.

Conclusion

The analysis in this chapter challenged common ideas about innovation in industry, namely that innovation is based solely on technological and scientific developments and pursued by firms in focussed attempts to increase competitive strength and profitability. In Finland, public policy has played a significant role in firms' orienting development activities over several decades. Firm behaviours are not simply about maximizing profits, but their activities and their innovation efforts are matching current thinking on what is crucial for the industry and for society. In terms of *innovation policy,* there seems to have been a general reorientation from a narrow focus on technological innovation as a source of economic growth in firms to a new and broader orientation in which regulations for sustainability are key drivers. The analysis of clear indications that industry has been integrated in this reorientation have been presented in this chapter. Hence, not only policy but also development activities in the industry have been transformed.

Environmental and climate issues are increasingly part of the policy strategies of Finland, as they are across the EU. The implementation of its strategies includes action plans, R&D programmes and broader regulation (sometimes implemented through directives). All of this has affected the situation in Finland. The study of selected firms in Finnish construction product manufacturing has illustrated how the global environmental and climate challenges have influenced the Finnish innovation activities of construction product manufacturers via the system of government and the industry organisations. The policy to reduce the environmental footprint of the construction sector and its related sectors has resulted in a new innovation and marketing focus in Finnish firms. This chapter has shown that this new focus is a result of several forces pulling in the same direction: Sustainability is a concern of customers, creating a demand pull. Public financing of research and innovation is geared more towards sustainability, creating a supply push from technology. In addition, not only because of the activities at the level of organisations, there seems to be a new motivation for moving towards environmental responsibility, because it is understood that this undoubtedly will be instrumental in promoting the reputation of firms and of the sector as a whole.

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