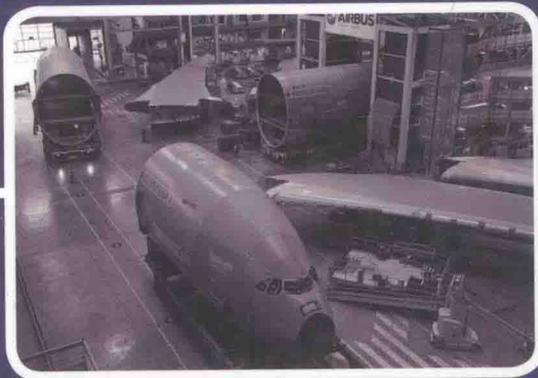


# Supply chain integration in the building industry

The emergence of integrated and  
repetitive strategies in a fragmented  
and project-driven industry



Ruben Vrijhoef



# Supply chain integration in the building industry

The emergence of integrated and  
repetitive strategies in a fragmented  
and project-driven industry



ter verkrijging van de graad van doctor  
aan de Technische Universiteit Delft,  
op gezag van de Rector Magnificus  
prof. ir. K.C.A.M Luyben,  
voorzitter van het College voor Promoties,  
in het openbaar te verdedigen op  
25 november 2011 om 10:00 uur

door Ruben VRIJHOEF

civiel ingenieur  
geboren 26 december 1972 te Wormerveer.

*Dit proefschrift is goedgekeurd door de promotoren:*

Prof.dr.ir. H.A.J. de Ridder

Prof.ir. H. de Jonge

Prof.dr.ir. B.A.G. Bossink

*Samenstelling promotiecommissie:*

Rector Magnificus, voorzitter

Prof.dr.ir. H.A.J. de Ridder, Technische Universiteit Delft, promotor

Prof.ir. H. de Jonge, Technische Universiteit Delft, promotor

Prof.dr.ir. B.A.G. Bossink, Vrije Universiteit Amsterdam, promotor

Prof.dr. P.S. Barrett, University of Salford

Prof.dr. W.P. Hughes, University of Reading

Prof.dr. J.A.A. van der Veen, Universiteit van Amsterdam

Prof.dr.ir. S.C. Santema, Technische Universiteit Delft

Prof.dr.ir. J.W.F. Wamelink, Technische Universiteit Delft

© 2011 Ruben Vrijhoef and IOS Press

All rights reserved. No part of this book may be reproduced, stored in a retrieval system, or transmitted, in any form or by any means, without prior permission from the publisher.

ISBN 978-1-60750-962-2 (print)

*Keywords:* building, manufacturing, supply chain, integration, comparison.

*Published and distributed by IOS Press under the imprint Delft University Press*

*Publisher*

IOS Press

Nieuwe Hemweg 6b

1013 BG Amsterdam

The Netherlands

tel: +31-20-688 3355

fax: +31-20-687 0019

email: [info@iospress.nl](mailto:info@iospress.nl)

[www.iospress.nl](http://www.iospress.nl)

LEGAL NOTICE

The publisher is not responsible for the use which might be made of the following information.

PRINTED IN THE NETHERLANDS



# Preface

The building industry is one of the oldest industries around. The ways of working within the industry have developed at their own pace over the years. The industry has been applauded for furnishing great works, providing populations with accommodations and infrastructures, and substantially contributing to economic growth and prosperity worldwide. However, the industry has also been criticised extensively for being wasteful, not innovative and unproductive. In those criticisms, reference is often made to other sectors of industry, particularly manufacturing, that functions and produces its products in more effective and efficient ways than the building industry does apparently. One of the major differences observed between building and manufacturing, among other things, has been the organisation and coordination of the supply chain. Such differences call for a careful consideration of the possibilities and impossibilities of transferring supply chain approaches from manufacturing to building.

The organisation and coordination of supply chains have been observed and conceptualised in different ways in building and manufacturing based on the specifically characteristic differences between those sectors. In building, the organisational approaches of supply chains have particularly been influenced by the one-off, temporal nature of projects; the large number of firms involved in the definition, design, manufacture and assembly of built objects involving many relatively small firms; the dispersed power and governance regimes; and the initiating

role of clients. These characteristics and other specific aspects of building have influenced how firms in the building industry operate, how they manage their inter-firm relationships, and in essence, how the industry as a whole is organised. In order to address improvements of this situation, managerial and organisational arrangements between firms in the building supply chain need to be reconsidered.

A more integrated approach to the supply chain has been suggested as a solution to the many problems and deficiencies existing in building. On the other hand, the restrictions on increasing the level of integration in building also need to be taken into account. The approach's underlying principle would be that the supply chain that is delivering a single product should not be fragmented nor consist of disconnected functions. Instead, supply chain integration would lead to a more stable and repetitive production environment, similar to what is common in manufacturing. The premise here is that the building supply chain would function better when approached and reconceptualised as a single entity, an extended enterprise. In a way, the deeper issue here is whether the building industry could or should develop itself towards the standards and practices of a more integrated and repetitively operating industry, such as manufacturing.

This thesis represents an exploration of that idea, and marks the end of a longer journey in that direction that has been ongoing for some years. A selection of parts of previous writings produced during this journey has become an integrated part of this thesis. The aspiration of the thesis is that it will contribute to the theoretical and practical development of the concept of supply chain integration and the positive effects it may yield for the building industry.

Ruben Vrijhoef

Delft

November 2011



# Acknowledgements

Doing a doctoral study and writing up the thesis is a lonely task. It is actually meant as a test for the researcher, to prove whether he or she is competent to perform such a task individually. However, it cannot really be done without the help of many. In fact, it is thanks to the support of many that this thesis is now finally lying before you. First, my thanks go to my supervisors, Hennes de Ridder, Hans de Jonge and Bart Bossink, for their continual support, criticism and patience. I want to thank Bart in particular for his help in getting me through the final process of writing up the thesis. I could not have done it without him. In addition, I want to thank Hans Wamelink for being so generous in allowing me to take some time off to write up the thesis. I want to thank Jelle Koolwijk for taking over my activities at the university and the centre during my absence. Thanks also to other colleagues at the university, clients and industry partners for their expressions of interest in my work and the thesis. In particular, I want to thank the PSIBouw innovation programme, Delft University of Technology and the Centre for Process Innovation in Building and Construction for their financial support of this thesis.

In the wider community, I want to thank my many colleagues around the globe for our inspiring debates at the many occasions and conferences where we met and discussed the subject of the thesis. Within this community, I want to thank

a few distinguished people in particular. Thanks go to my first academic mentor and supervisor, Lauri Koskela, for introducing me in 1997 to this intriguing realm of research while I was finishing my master thesis in Finland, and selling me on the idea of embarking on a doctoral study in the first place. Parts of this thesis are based on previous papers I wrote that have now shown to be part of the longer journey of writing this thesis bit by bit during the last couple of years. In a few cases, the papers were co-written with colleagues around the globe, notably Kerry London, William O'Brien, Carlos Formoso, Hans Voordijk and Lauri Koskela. Thanks to you all for the collaborative writing and being able to reuse and adapt a few parts of the texts, particularly in the first part of the thesis. With respect to the empirical part of the thesis, particularly the building case studies, I want to thank all respondents and informants involved for contributing their input and time so generously. I would like to thank Roberta Hardy for her valuable corrections of the English, and Corien Smit for doing a wonderful job on the design and the layout of the thesis.

To conclude, my thanks go to the smaller community of my friends, relatives and family. I want to thank you all equally for your interest, support and the distraction from this work I needed every now and then. There are four people I want to thank especially: my mother-in-law, Wil, for helping me out with the transcripts of the interviews, and last and most especially, my thanks go to my dearest Marianne, Pepijn and Meinou for your endless confidence, patience and love. This thesis is dedicated to you.





# Table of Contents

Preface .....	v
Acknowledgements .....	vii
1 Introduction .....	1
1.1 Background: understanding the building industry as a project-driven industry .....	1
1.2 Research problem: fragmentation and lack of repetition in the building supply chain ...	4
1.3 Rationale: the concept of supply chain integration as a development path for the building supply chain .....	7
1.4 Research objective: specifying a concept of supply chain integration for the building industry .....	11
1.5 Research questions: achieving the objective of a concept of supply chain integration for the building industry .....	13
1.6 Limitations and justification: scope and relevance .....	14
1.7 Structure of the thesis: parts and chapters .....	15
1.8 Reflection on key issues and contributions of this chapter to the thesis .....	17
2 Research design .....	19
2.1 Research approach: contributing to theory and practice .....	19
2.1.1 This research viewed as organisational qualitative research .....	19
2.1.2 This research viewed as knowledge production .....	21
2.1.3 This research viewed as theory building .....	22

2.2	Research strategy: theory building from case study research .....	23
2.3	Structure of the research: research stages and activities .....	26
2.3.1	Part I: Theoretical basis .....	26
2.3.2	Part II: Empirical analysis .....	26
2.3.3	Part III: Synthesis .....	28
2.4	Justification of the research approach .....	30
2.4.1	Validity .....	30
2.4.2	Reliability .....	31
2.4.3	Generalisability .....	31
2.5	Reflection on key issues and contributions of this chapter to the thesis .....	31

## PART I: THEORETICAL BASIS ..... 35

### 3 Framing the concept of supply chain integration in building ..... 37

3.1	The idea to learn and transfer supply chain concepts from other industries to the building industry .....	39
3.1.1	General lessons from manufacturing as potential solutions for building .....	39
3.1.2	Differences between industries as a potential hindrance transferring concepts .....	40
3.2	Previous thoughts pointing towards supply chain integration in building .....	41
3.2.1	Quasi-firm and extended enterprise .....	41
3.2.2	Supply chain management .....	42
3.2.3	System integrator .....	43
3.3	Contributing topics to supply chain integration in the building industry .....	44
3.3.1	Integrated contracts and strategic procurement .....	45
3.3.2	Alliances and partnering .....	46
3.3.3	Lean and agile construction .....	47
3.3.4	Co-makership .....	47
3.3.5	Just-in-time logistics .....	48
3.3.6	Modularisation, standardisation and postponement .....	48
3.3.7	Prefabrication, offsite construction and industrialisation .....	49
3.4	Reflection on key issues and contributions of this chapter to the thesis .....	49

### 4 Theoretical framework ..... 53

4.1	Explaining the need for a multiple theoretical view on the supply chain and the selection of the four perspectives .....	53
4.2	Introducing the four theoretical perspectives on the supply chain .....	57

4.2.1	Economic perspective: transaction cost economics .....	57
4.2.2	Production perspective: production management .....	59
4.2.3	Organisational perspective: inter-firm networks .....	60
4.2.4	Social perspective: communication and commitment .....	61
4.3	Applying the four theoretical perspectives to the building supply chain .....	61
4.3.1	Economic perspective: transaction cost economics .....	61
4.3.2	Production perspective: production management .....	63
4.3.3	Organisational perspective: inter-firm networks .....	63
4.3.4	Social perspective: communication and commitment .....	64
4.4	Synthesising the theoretical framework .....	65
4.5	Reflection on key issues and contributions of this chapter to the thesis .....	66
5 Analytical model for supply chain integration .....		69
5.1	Operationalising the theoretical framework into factors of analysis .....	69
5.1.1	Economic governance of the integrated supply chain .....	73
5.1.2	Production management of the integrated supply chain .....	74
5.1.3	Inter-organisational governance of the integrated supply chain .....	75
5.1.4	Social governance of the integrated supply chain .....	77
5.2	Identifying four development levels of supply chain integration .....	80
5.3	Relating the factors of analysis to the four development levels .....	81
5.4	Reflection on key issues and contributions of this chapter to the thesis .....	84
PART II: EMPIRICAL ANALYSIS .....		87
6 Supply chain integration practices in manufacturing .....		89
6.1	Implications of conceptual investigations across industries .....	89
6.2	Explanation of the selection of manufacturing industries .....	91
6.2.1	Industry typology .....	91
6.2.2	Supply chain typology .....	92
6.2.3	Industries selected for this thesis .....	95
6.3	Supply chain integration practices applied in the automotive industry .....	96
6.3.1	Example of consumer cars: Toyota .....	98
6.4	Supply chain integration practices applied in the aerospace industry .....	101
6.4.1	Example of aircrafts: Airbus .....	103
6.5	Supply chain integration practices applied in the computer industry .....	106
6.5.1	Example of personal computers: Dell .....	107
6.6	Supply chain integration practices applied in the electronics industry .....	110
6.6.1	Example of semiconductor machines: ASML .....	112

6.7 Supply chain integration practices applied in the clothing and textile industry .....	115
6.7.1 Example of fashion: Zara .....	117
6.8 Supply chain integration practices applied in the food and grocery sector .....	121
6.8.1 Example of groceries: Wal-Mart .....	123
6.9 Reflection on key issues and contributions of this chapter to the thesis .....	128

## 7 Supply chain integration practices in the building industry ..... 131

7.1 Outline of the building case studies .....	131
7.1.1 Cases selected for this thesis .....	131
7.1.2 Organisation of case descriptions .....	134
7.2 Supply chain integration practices applied by clients .....	134
7.2.1 Case of a housing corporation in operational cooperation with builders (Client 1) .....	134
7.2.2 Case of a housing corporation in legal partnership with builders (Client 2) .....	140
7.3 Supply chain integration practices applied by developers .....	145
7.3.1 Case of a full-service project developer (Developer) .....	145
7.4 Supply chain integration practices applied by designers .....	149
7.4.1 Case of a developing and contracting architect (Designer 1) .....	149
7.4.2 Case of an architectural engineer (Designer 2) .....	153
7.5 Supply chain integration practices applied by builders .....	156
7.5.1 Case of a catalogue builder (Builder 1) .....	156
7.5.2 Case of an ICT-driven builder (Builder 2) .....	160
7.5.3 Case of a lean-driven builder (Builder 3) .....	164
7.6 Supply chain integration practices applied by suppliers .....	168
7.6.1 Case of three suppliers integrating products and site installation (Suppliers) .....	168
7.7 Reflection on key issues and contributions of this chapter to the thesis .....	173

## PART III: SYNTHESIS ..... 177

### 8 Case study analyses ..... 179

8.1 Analyses of the building case studies .....	179
8.1.1 Within-case analyses of the building cases .....	179
8.1.2 Cross-case analysis between the building cases .....	190
8.2 Analyses of the manufacturing comparator studies .....	192
8.2.1 Within-case analyses of the manufacturing comparators .....	192

8.2.2 Cross-case analysis between the manufacturing comparators .....	196
8.3 Comparative analysis between building and manufacturing .....	200
8.4 Reflection on key issues and contributions of this chapter to the thesis .....	201
9 Conclusions .....	207
9.1 Theory building: confronting theory with practice .....	207
9.1.1 Identifying the relationships supporting the hypotheses .....	209
9.1.2 Relating and clustering the theoretical factors .....	220
9.1.3 Relating and clustering the goals .....	223
9.1.4 Shaping the hypotheses .....	228
9.2 Answers to research questions .....	232
9.3 Contributions to theory and method .....	234
9.4 Implications for building practice .....	235
9.5 Directions for further research .....	237
References .....	243
Appendices .....	281
Case Study Protocol .....	281
Themes retrieved from coding .....	284
Data gathering in the manufacturing cases .....	286
Data gathering in the building cases .....	288
Glossary of Abbreviations and Terms .....	290
List of Figures .....	297
List of Tables .....	299
Summary .....	305
Samenvatting (summary in Dutch) .....	311
Curriculum Vitae .....	317
Publications .....	319

# 1 | Introduction

The building industry can be typified as a project-based industry with specific characteristics such as location-bound design, one-off production, changing production coalitions per project, outdoor and environmental circumstances, multiple clients and multiple suppliers involved in a single project. In comparison to many other industries, the production environment in building is relatively complex and unstable. This generally leads to negative effects, such as low levels of effectiveness and efficiency, low rates of innovation and impediments to knowledge sharing and learning. The performance level of the building sector is considered to be lower and lagging behind other industrial sectors. The introduction of more integrated and multi-project ways of working and collaboration such as those seen in other industrial sectors would seem logical and beneficial. One pathway towards these kinds of solutions is provided by the *concept of supply chain integration*. In manufacturing, supply chains have typically been integrated by focal companies, linking and synchronising suppliers' processes to their own business processes through applications of supply chain integration. This thesis represents a quest to construct a concept for supply chain integration in the building industry.

## 1.1 Background: understanding the building industry as a project-driven industry

In previous research as well as in practice, the building industry has been criticised for its supposed low level of performance and backwardness in many respects

(Woudhuysen & Abley 2004). The causes of the problematic character of building apparently lie in the very *nature of building*, and have been sought at the level of the product, the production in projects, and the industry as a whole. The nature of building has been blamed for contributing to waste and value loss, and it has been claimed that it is necessary to transform this or at least to mitigate the impact on the level of production (Koskela 2000). However, to achieve 'full resolution', it often seems that a particular characteristic has to be mastered at multiple levels of the production system. The industry's characteristics on the production level are related to characteristics on both the product and industry levels (Figure 1). The three levels of characteristics reinforce each other in a complex interaction, which contributes to the difficulty of reducing the problems of building and thus also to the persistence of the *problematic character* of building (Koskela 2000).

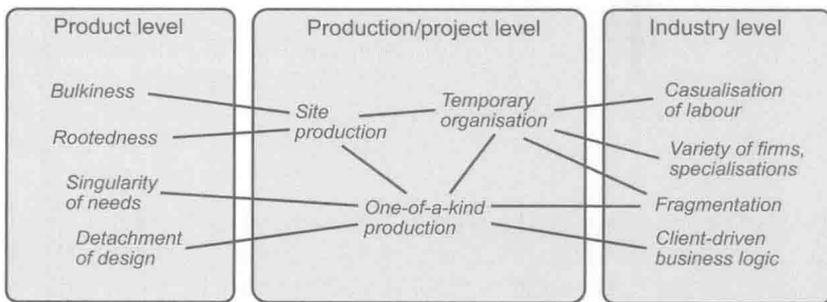


Figure 1: Three characteristics of building on product, production and industry level.

Adapted from (Vrijhoef & Koskela 2005b)

The *basic characteristics* of built objects have been viewed as causing limitations to technology and problems in the management of building projects (Nam & Tatum 1988). In this context, various features have been mentioned, such as immobility, complexity, long product life cycle, capital intensity and impact on the environment. In addition, built objects are often unique with additional specific features, and they are built in a specific institutional and socio-economic context. At the industry level, there are high levels of *fragmentation*, a wide variety of firms of different specialisation and size, and high levels of casualisation of labour. In some cases it has even been questioned whether building can be regarded as an actual industry (Groák 1994), or more properly as a 'loosely coupled system' of projects (Dubois & Gadde 2002). Paradoxically, however, fragmentation of the industry must not be seen as strictly problematic. The involvement of many different specialised firms in projects does not necessarily cause low levels of efficiency. On the contrary, it has been claimed that this could just as well increase the efficiency of resource allocation and speed of information exchange between parties (Pryke 2002).

Still, the product, process and industry characteristics of building do have an impact on the *production situation* and the way in which building projects are organised. Building projects have been described as *coalitions of firms*; i.e. 'a number of independent firms coming together for the purpose of undertaking a single building project and that coalition of firms having to work as if it were a single firm, for the purposes of the project' (Winch 1989). The parties involved in building projects have been interpreted as 'organisational units joining and operating together as a single production organisation when it is advantageous' (Harland et al. 1999); a 'temporary multiple organisation' (Cherns & Bryant 1984); or a 'quasi-firm' (Eccles 1981). The production system has been regarded as 'capability-oriented production' (Wortmann 1992), and is always locally bound and thus dependent on physical factors such as soil and weather conditions.

The *organisation of production* and the supply chains is strongly aimed at the convergence of logistics to a particular site, and delivery of the one-off, customised and capital-intensive product to a single end customer (Lin & Shaw 1998). This has previously been identified as the 'prototype nature' of building (Koskela 2000), reflected most characteristically by the predominant one-off approach in discrete building projects, i.e. 'unique-product production' (Drucker 1963). These characteristics of the production organisation in the building industry are not unique as such and can also be found in other sectors of industry, but it is the specific *combination of characteristics*, which apparently makes the building situation unique. This implies that *concepts from other industries* could be applicable to the building industry if the combined characteristics of building and their causal relationships are addressed (Figure 2). The characteristics of building could be overcome or resolved in practice by *adapting* those concepts and *translating* them into a building context.

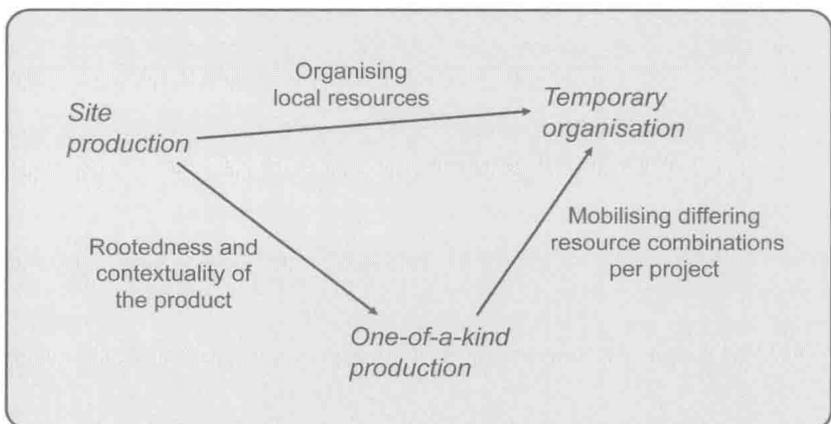


Figure 2: Characteristics of building and their causal relations (Vrijhoef & Koskela 2005b)

## 1.2 Research problem: fragmentation and lack of repetition in the building supply chain

Because of its project-based approach, the production system of the building industry is highly flexible and fragmented, consisting of many different subsectors (residential, commercial, etc.), many different disciplines (developers, builders, engineers, architects, etc.), and a wide spectrum of firm sizes with a relatively high share of SMEs. This has led to relatively high levels of *fragmentation* of the building supply chain from supplier to end user. Building projects are usually initiated by a client organisation, such as a housing corporation. On both the demand and the supply side, many parties play a role, including a large number of stakeholders on the demand side as well as a large number of co-producers on the supply side (Figure 3).

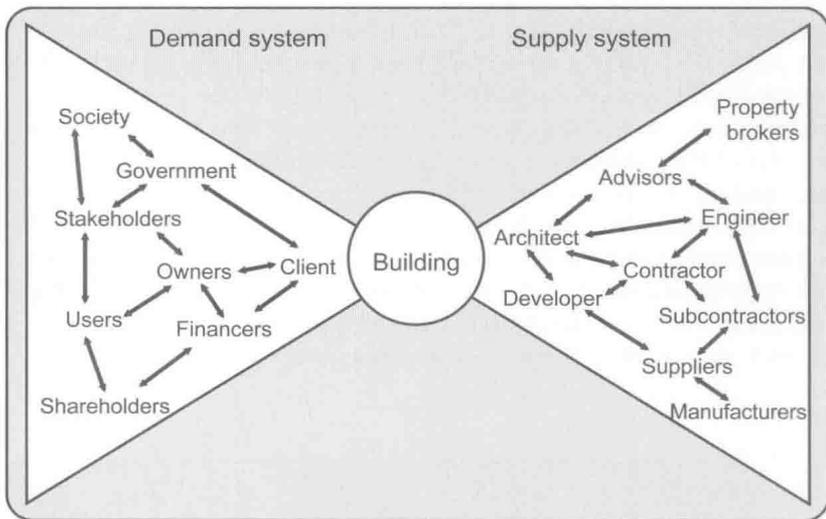


Figure 3: Schematic representation of the demand and supply system around a built object (Vrijhoef & De Ridder 2005)

Firms in the building industry work together in constantly changing coalitions on different building projects (O'Brien et al. 1995). This is particularly true in a traditional building setting, where multiple bilateral contracts are negotiated between individual parties who are involved in a temporary coalition until the completion of the project. As a result, the constructed product is seldom predefined, but instead the delivery of built products can be typified as assemble-to-order, make-to-order, design-to-order or even concept-to-order (Luhtala et al. 1994, Winch 2003) (Figure 4). This makes building essentially a demand-driven process that is