Integrating Lean Design and Lean Construction
Processes and methods

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Abstract

Inspired by the industrial manufacturing debate of the late 1980s and the early 1990s, lean construction emerged from attempts of transferring and applying a Japanese (lean) production philosophy to the construction industry. Application of the lean philosophy - which prescribes the enhancement of value and elimination of waste as perceived by the end customer - has diffused slower and more uneven into construction compared to manufacturing, where it became a leading production and management trend of the 1990s and the first half of the 2000s. However, lean construction has become a well established theme on the construction agenda in some countries (e.g. in Denmark and the UK). Hitherto lean construction has, in debate and practice, primarily focussed on production aspects. Gradually, however, design issues have started to receive more attention and lean application to construction design is commonly referred to as lean design. Another important theme of recent years’ debate on developing the construction industry and its project delivery practices is integration of project processes which has often been identified as a key issue regarding construction performance improvement. Issues of integration of construction design and production activities from a lean perspective are beginning to be addressed by the construction industry but have not yet been thoroughly and systematically investigated. Motivated by this situation this thesis aims to address the following two research questions:

Research question 1: Is the lean philosophy appropriate as a means for pursuing integration of construction design and production processes?

Research question 2: Which processes and/or methods and/or issues are crucial or critical for integrating construction design and production from a perspective of the lean philosophy?

A review of literature on the lean philosophy and its application to manufacturing industries and construction reveals that the lean philosophy is highly interpretive and that there is no shared definition or understanding of what is meant by ‘lean’, ‘lean production’, ‘lean construction’ etc.

Regarding the first research question it is concluded that as a means for pursuing design/construction process integration the lean philosophy can be appropriate, though not on its own, and provided that the notion of ‘end customer’ is (re)defined to represent a wider range of construction stakeholders including wider society.

The second research question is explored through previous research and the findings from three ethnographic case studies from Denmark and USA. On this basis it is concluded that processes/methods crucial or critical for pursuing design/construction integration from the perspective of the lean philosophy are:

- Value identification, specification and communication;
- Establishing an appropriate project delivery framework;
- Project organisation, structuring and planning of delivery processes;
- Establishing transparency;
- Management and leadership, and;
- Learning.
The main contribution of this research is, in the larger perspective of the construction debate, a comprehensive review of literature on ‘lean’ and an analysis and discussion of how the lean philosophy and its pivotal point of end customer focus can be meaningfully understood in relation to the context of construction.

It is suggested that future research should examine the three following themes:

- Whole-life value and waste identification;
- Transparency regarding value/waste consequences of project and design decisions, and;
- Project delivery framework supporting lean application.
Dansk resume

Inspireret af de sene 1980eres og tidlige ’90eres brede interesse for japanske produktions- og ledelseskoncepter i fremstillingsindustrierne, opstod *lean construction* ud fra ønsket om at overføre ideerne fra den japanske produktionsfilosofi ’*lean*’ til byggeriet. Lean-filosofien, som foreskriver styrkelse af slutkundeværdi og eliminering af spild, har i byggeriet opnået langsommere og mindre omfattende udbredelse end i industrien, hvor ’*lean*’ igennem en årrække har været en førende ledelsesmode. Dog er *lean construction* i nogle lande blevet et etableret tema på byggeriets dagsorden (bl.a. i Danmark og i Storbritannien). Længe fokuserede *lean construction* primært på produktionsaspekter, men gradvist er projekteringsaspekter blevet taget op, ofte under betegnelsen ’*lean design*’. Et andet væsentligt tema fra de senere års debat om byggeriets udvikling er *integration* af byggeriets processer, hvilket ofte har været fremhævet som en nøgletema for byggeriets produktivitetsudvikling. Integration af projektering og udførelse med udgangspunkt i et *lean-perspektiv* er et emne, som i stigende grad trækker sig byggebranchens opmærksomhed, men som endnu ikke er grundigt eller systematisk udforsket. Heraf udspringer motivationen bag denne afhandlings to forskningsspørgsmål:

Forskningsspørgsmål 1: *Er Lean-filosofien et egnet redskab i forbindelse med bestræbelser efter integration af byggeriets projektering- og udførelsesprocesser?*


En gennemgang af litteratur om *lean-filosofien* og dens anvendelse i industri og byggeri afslører, at *lean-filosofien* i høj grad er åben for fortolkning, og at der ikke findes nogen fælles definition af ’*lean*’, ’*lean production*’, ’*lean construction*’ osv. Angående det første forskningsspørgsmål konkluderes, at i bestræbelser på integration af byggeriets projektering og udførelse *kan* *lean-filosofien* tilbyde et hensigtsmæssigt perspektiv, men ikke hvis det får lov at stå alene, og kun såfremt slutkundebegrebet omdetermines til at repræsentere et bredere udsnit af interessenter og samfundsinteresser.

Det andet forskningsspørgsmål er efterforsket med udgangspunkt i tidligere forskning og tre etnografiske casestudier fra Danmark og USA, og det konkluderes, at følgende processer/metoder er afgørende eller kritiske for bestræbelser på at integrere projektering/udførelse ud fra et *lean-perspektiv*:

- Værdiidentifikation, -beskrivelse og –kommunikation;
- Etablering af hensigtsmæssige forhold og strukturer omkring projektgennemførelse;
- Selve projektoorganiseringen og planlægningen af projektprocesser;
- Etablering af gennemgripethed;
- Ledelse og styring, og
- Læring.

I et bredere byggeforskningsperspektiv er dette forskningsprojekts væsentligst bidrag en omfattende gennemgang af *lean-litteratur* og en analyse og diskussion af, hvorledes...
lean-filosofien og dets kardinalpunkt, slutkundefokus, kan forstås i forhold til byggeriets kontekst.

Det anbefales, at fremtidig forskning undersøger følgende temaer:

- 'Whole-life’ værdi- og spildidentifikation;
- Gennemsigtighed vedrørende værdi-/spildkonsekvenser af projekt- og projekteringsbeslutninger, og

Projektforhold og -strukturer som understøtter en lean-tilgang.
Preface

The motivation for a Ph.D. within the field of 'lean' construction

The motivation behind the choice of lean construction as a research subject finds its explanation in circumstances present in spring 2003 when my research proposal was being formulated. At the time ‘lean construction’ was perhaps the most promoted initiative in the Danish construction debate and heavily promoted by trend-setting clients and leading contractors. The promotion of ‘lean construction’ was further emphasised by the establishment of a Danish branch of the Lean Construction Institute (Lean Construction Danmark), which was broadly supported by the construction sector as well as by the labour movement which acted as one of its the most visible proponents. Implementation of construction management concepts branded with a ‘lean construction’ label was under way on Danish construction sites. Leading companies aspired to extract tools and methods from lean construction concepts - mainly the Last Planner System of Production Control (Ballard 1994; 2000a) – and implement them upstream into the construction design phases under the headline ‘lean design’, with the explicit aim of obtaining a better integrated ‘lean’ project execution. Therefore, if applying just a pure relevance criterion for choosing a research topic, the above developments within the Danish construction sector put forward a ‘rational’ (and ‘academic’) argument for conducting research on the on-going efforts of integrating design and construction from a lean perspective.

Another set of reasons, perhaps more ‘political’ or ‘strategic’ in nature, arguing in favour of choosing lean construction as a research topic, was the importance of a) having a doctoral research proposal approved by the university, and b) obtaining access to empirical material from practice - which is essential for research but not necessarily easy in every case. I had previously (in 2002 when working on my master’s thesis) conducted a pilot study on the implementation of lean construction from a change management perspective, which had provided me some experience and industry contacts that were considered as a potential advantage in order to obtain the university’s approval of the research proposal.

The research project developed from a sequence of processes of alternating ‘emergence and agency’1, where complex patterns of external circumstances provided a dynamic framework of possibilities and limitations amongst which I sought to influence my own position with the aim of obtaining a research grant for studies within the field of construction management. In brief it can be said that the research topic was chosen from the simple criteria that it combined a field of high relevance that, without controversy, begged for further study, with practical possibilities of achieving and carrying through an actual research project. In other words, the research topic can be seen as having been ‘self-selecting’.

Some critical reflections on my position throughout the research project

Given the circumstances described above, I became aware during the project that different kinds of innovation studies tend to have a pro-innovation bias (Rogers 2003)

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1 For an elaborate discussion on emergence and agency in organisational context, see (Stacey 2005).
and that a considerable part of the studies published under the headline ‘lean construction’ appeared – as argued by Green (2002) – to have a significant bias in favour of lean construction since only a few publications took a critical approach, or criticised the unilateral promotion of lean construction. Such publications as the ‘Egan Report’ *Rethinking Construction* (DETR 1998) explicitly emphasised ‘lean construction’ as a way forward in tackling productivity and quality problems of the construction industry, though without presenting any evidence to support this position (Green 2002), nevertheless had a great impact to the perception of lean e.g. in Denmark and the UK. Therefore critical reflection on what role I myself had in relation to the research topic was of a crucial importance. The fact that the topic studied is highly politicised also required that I made such circumstances and their possible impact explicit.

At the commencement of the work - being fully aware of the importance of conducting the research from a position as neutral possible and drawing conclusions from the actual findings only – I carefully considered my position in relation to the research. Acknowledging the impossibility of a researcher ever reaching complete neutrality in a position where he is bound to inflict some measure of influence through his/her choices and interpretations, and through the research approaches opted for, I was however also aware that my initial impression regarding ‘lean construction’ had, in fact, been partial.

I realised that I had possibly, but without being conscious thereof, begun my research with a positive bias – a realisation that motivated taking a critical and self-critical approach to the work. In retrospect the originally favourable, rather than neutral view, appears to have derived partly from the very biased promotion of lean construction by construction stakeholders: construction companies and labour unions as well as client organisations and public authorities - and partly from the expectation that the stakeholder consensus in directing attention to efforts of improving existing building processes could in itself contribute to systematic development. It cannot be ruled out that my position may also have been influenced by the promotion of lean construction as something different from previous practices by supposedly being ‘scientifically based and validated in terms of theoretical argument and empirical evidence’, as was claimed by the local lean construction community. Clearly ‘lean construction’ in Denmark had become a bit of a trend that kept receiving praise from all around. A number of observations made prior to the setting up of the research project supported this perception:

- There was an entirely one-sided promotion of ‘lean construction’ and an impressive range of stakeholders took explicit stand in favour of ‘the new construction process’ that was presented as something that should be applied, without much reflection on the cultural and sociological implications of changing practices. Furthermore advocates often appeared to be without first hand experience of lean construction.

- There was a remarkable contrast between the plurality of proponents and the dominating explanation of lean construction being, as propagated by a very visible local lean construction consultant, the ‘scientific method’ based on advanced mathematical concepts of chaos theory etc. It was obvious that the vast majority of those promoting ‘lean construction’ did not in fact possess insight into chaos theory etc. and were not themselves able to present
empirical evidence (or even indications) of the positive effects of lean construction. Thus one would suspect that their belief in the methods promoted was built mostly on trust in the expertise of others.

- The first company in Denmark to adopt ‘lean construction’ - which it used heavily for PR purposes – publicly stated that at projects where lean construction was applied this reduced construction time with 20% and costs with 10% when compared to projects executed through ‘the traditional method’. The responsible executive stated that the company believed that their new lean construction concept would make the net profit margin for the entire company group double. Nevertheless, the company only applied lean construction to some of its projects, and initially only in its house-building division. The company employed one full and one half time internal consultants and organised a one time one-day course in ‘lean construction’ for project and contract managers. For a construction company with a turnover exceeding €1B this has to be considered a remarkably modest investment in comparison to its official expectations and reported initial results from lean construction. Under these circumstances it was difficult to imagine that the company actually expected as much from ‘lean construction’ as it claimed.

Despite these rather clear indications of overly-optimistic ‘lean construction hype’, I believed in the existence of convincing scientific merits of ‘lean construction’. Both technical universities in Denmark were involved in the lean construction community without me ever hearing a single academic utter a critical word, question lean construction or the strong promotion for it. At that time I (yet inexperienced) could not believe that the obvious support from the academia was not based on very thoroughly validated research critically conducted or examined by these institutions. I was fortunate to enjoy the advantage of working under the supervision of a non-Danish professor who, being new to the Danish construction environment, was also not socialised in the local research community and its culture. Hence the supervisor was in a good position to take a different point of view on the context of lean construction. The supervisor thus made an active ‘sparring partner’ and was good at asking critical questions that forced me to reflect upon my assumptions, conscious as well as the unconscious.

During the research process and upon gathering and analysing information on lean construction I was, however, forced to re-asses my confidence in the reliability of Danish construction management research and academia in respect to its position on lean construction. Studying the available publications and research on ‘lean construction’ and its origins in manufacturing soon revealed a considerable gap between the public (Danish) image of lean construction and what could actually be validated. This, among other experiences, radically changed my conception and perception, of not only ‘lean construction’, but also led to me to modify my general expectations in research and in the academia. Bluntly speaking, my belief on the integrity of academia was challenged – something which retrospectively appears as having provided a young researcher with an eye-opening experience and a lesson.

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2 An elaboration of the statement can be found in an article from the Danish newspaper Jyllandsposten (October 2nd 2001, Erhverv og Økonomi, p. 2). In the same article it is stated that the company’s analysis showed that if the construction sector generally adopted ‘the new method’ and became 10% more efficient, the GNP of Denmark would increase with as much as 4%.
taught about the importance of always reflecting critically on research (others’ as well as one’s own!) and never let go of a last remnant of doubt and scepticism in even the most established scientific and well-documented beliefs and assumptions. This motivated diligent scrutiny of lean construction and sharpened the critical analysis of other researchers’ input on lean construction. When the research project and the collecting of empirical data approached finalisation I defined myself in a very different position in relation to the research topic than in the beginning of the project.

Finally it is also important to reflect critically upon my position in relation to the design/production integration. The feasibility of construction design/production integration has not been studied in this research, which has taken as its point of departure the actual agenda of developing an integrated approach to lean design and lean construction. I have therefore been limited to investigating possibilities and limitations for achieving this. No position has been taken regarding whether design/production integration is feasible in the first place. Professor Stephen Kendall, Ball State University, argued in his keynote speech at the CIB W096 Special Meeting ‘Designing Value’ in November 2005, that contemporary construction research discussing design/production integration often appear to work from the implicit presumption that a high degree of integration is desirable – but that this generalisation remains yet to be proven. Taking note of Professor Kendall’s criticism that there is little critical reflection on the basic feasibility of integration in the first place, this thesis shall make this concern explicit. However, investigating this question in the depth it deserves would require a whole different research project.

To conclude, I had to ascertain that there is no universal definition of ‘lean construction’ (discussed in detail in Chapter 3) and that ‘lean construction’ took very different manifestations around the world when applied in practice (for an example, see (Jørgensen et al. 2005)). Thus the terms ‘lean construction’- and ‘lean design’ signified only little meaning *per se*, though what mattered in practice was which, and what kind, of initiatives these terms were used to describe. Hence the thesis evolved and greater emphasis was needed on definitions and conducting a thorough review of the research on lean construction and lean manufacturing. The result of this thesis is a critical, yet balanced, research project which, I hope, other researchers and practitioners can take forward.

Bo Jørgensen
Copenhagen, May 2006

3 I later realised that construction researchers in Denmark often work under very difficult conditions which I now understand must be taken into consideration before expecting that academia will provide a lighthouse for navigation through the troubled waters of myth and reality of the lean construction debate.
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- **Stephen Emmitt**: Hoffmann Professor of Innovation and Management in Building at the Technical University of Denmark and my supervisor. According to Umberto Eco one should not thank the supervisor since he/she is only doing his/her job... But I think that I can thank Stephen for having done more than ‘just’ his job. I do not recall having heard of other supervisors giving their students as much freedom and room to ‘fly the kite’ while also supporting them as much as he has supported me. - I should perhaps have told him sometime earlier but I happened to find it more convenient to leave him under the impression that he was just doing his job… (Besides, who was I to teach a professor?)

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⁴ Anyway, David, Carlos Eduardo, Sergio, Marcus etc., you all know to whom I am referring.
# Table of contents

Abstract .................................................................................................................................... 3
Dansk resume .......................................................................................................................... 5
Preface .................................................................................................................................... 7
The motivation for a Ph.D. within the field of ‘lean’ construction ........................................ 7
Some critical reflections on my position throughout the research project ......................... 7
Acknowledgements ............................................................................................................. 11
1. Introduction ..................................................................................................................... 19
   1.1. A historical perspective of modern construction organisation .................................. 19
   1.2. Characteristics of construction .............................................................................. 20
   1.3. Construction – a criticised sector ......................................................................... 22
   1.4. ‘Lean’ – a Japanese management innovation ......................................................... 22
       1.4.1. ‘Lean’ in construction ...................................................................................... 23
   1.5. Lean construction adopted as strategy for improvement ........................................ 23
       1.5.1. ‘Lean design’ .................................................................................................. 24
   1.6. An agenda for design/ construction integration .................................................... 25
   1.7. Gap in knowledge ................................................................................................. 27
   1.8. Purpose of the research ......................................................................................... 27
       1.8.1. Research questions ......................................................................................... 27
   1.9. Structure of dissertation ....................................................................................... 28
       1.9.1. A few comments on terminology .................................................................. 29
2. Research strategy and method ......................................................................................... 33
   2.1. Identifying information for answering the research questions ............................... 33
   2.2. Research strategy .................................................................................................... 33
       2.2.1. Focus and scope of research – limitations ...................................................... 34
   2.3. Literature studies – defining focus ......................................................................... 34
       2.3.1. Judging and weighting publications: academic, debate, opinion .................... 37
   2.4. Case study: design and method ............................................................................ 37
       2.4.1. Multiple case studies ...................................................................................... 37
       2.4.2. Data collection ............................................................................................... 38
       2.4.3. Establishing quality in case studies ............................................................... 39
       2.4.4. Non-participant observation ......................................................................... 40
       2.4.5. Project material/documents .......................................................................... 42
       2.4.6. Interviews ...................................................................................................... 42
       2.4.7. Application of questionnaires (Case II & III) .................................................. 43
       2.4.8. Comments on methodology for the individual case studies ......................... 45
       2.4.9. Reflections over ethical issues ........................................................................ 46
       2.4.10. Concluding remarks .................................................................................... 47
3. Towards an understanding of ‘lean’ ................................................................................. 51
   3.1. Introduction to ‘lean’ - a philosophy of enhancing value and reducing waste ........ 51
   3.2. History and development of the management concept ‘lean’ ................................. 52
       3.2.1. The term ‘lean production’ and its origin ......................................................... 52
       3.2.2. Origin and development of the Japanese model ‘lean production’ ................. 56
       3.2.3. The meaning of ‘lean production’ – different definitions ............................... 60
       3.2.4. Waste and value ............................................................................................ 69
       3.2.5. Lean design and product development ............................................................ 70
   3.3. The transfer of a manufacturing philosophy from car production in Japan to construction in the West ................................................................. 71
       3.3.1. The meaning of lean construction – different definitions ............................... 73
       3.3.2. Lean design in construction .......................................................................... 81
### Table of contents

3.4. Conceptual framework for ‘lean’ application to construction ............... 82
  3.4.1. The ‘lean’ philosophy and its application to the built environment .... 83
  3.4.2. Production planning, control and management ............................... 83
  3.4.3. Production system design and construction project design ............... 88
  3.4.4. Design management ....................................................................... 90
  3.4.5. Implementation .............................................................................. 94

3.5. Lean construction critique ................................................................. 95
  3.5.1. Lean production/manufacturing critique ......................................... 96
  3.5.2. Critical debate on Lean construction ............................................... 100

3.6. Working definition for ‘lean design’ and ‘construction’ ......................... 106
  3.6.1. Choice of working definition ......................................................... 107

3.7. Design/construction integration – choice of approach .......................... 108
  3.7.1. Design/construction integration in a lean perspective ....................... 110

4. Case I: Housing project in Denmark ...................................................... 113
  4.1. Case description - introduction ......................................................... 113
  4.2. Case history ...................................................................................... 113
    4.2.1. The tender process ...................................................................... 114
    4.2.2. About the project parties ............................................................. 115
    4.2.3. Background ................................................................................ 115
  4.3. The project organisation ................................................................... 115
    4.3.1. Design committee’s strengthened role ......................................... 116
  4.4. Project delivery strategy ................................................................... 117
    4.4.1. Standard housing units ............................................................... 117
    4.4.2. Development themes .................................................................... 118
    4.4.3. Lean design and lean construction .............................................. 118
    4.4.4. Partnering - transparent project economy ..................................... 119
    4.4.5. Proactive involvement of sub-contractors in the design process ...... 120
  4.5. Progress of the project: design start up and discontinuation ................. 120
    4.5.1. Project postponements .................................................................. 120
  4.6. Findings: Outcome of the project delivery strategy ............................. 121
    4.6.1. Standard housing units ............................................................... 121
    4.6.2. Development themes .................................................................... 121
    4.6.3. Application of lean design and lean construction .......................... 124
    4.6.4. Partnering - transparent project economy ..................................... 125
    4.6.5. Subcontractor involvement ............................................................ 127
  4.7. Summary of findings ......................................................................... 127
    4.7.1. Lean elements .............................................................................. 128
    4.7.2. Integration indicators .................................................................... 129

5. Case II: Rehab-housing units in Denmark .............................................. 133
  5.1. Case description ................................................................................ 133
    5.1.1. About the key participants .......................................................... 134
    5.1.2. Background ................................................................................ 135
  5.2. Project organisation ........................................................................... 136
  5.3. Project delivery strategy ..................................................................... 136
    5.3.1. Specific project challenges ......................................................... 137
  5.4. Findings ............................................................................................. 138
    5.4.1. Partial implementation of the Last Planner System in design .......... 139
    5.4.2. Participant engagement and collaborative design ......................... 140
    5.4.3. Fixed design a source of uncertainty ........................................... 140

Bo Jørgensen (2006)
5.4.4. Diverting interpretations of the demand for ‘environmentally correct
design’ ................................................................. 141
5.4.5. Participants perceiving divergent signals from the municipality .............. 144
5.4.6. Limited transparency of project economy and decisions ......................... 146
5.4.7. Management with maximum control of economy and schedule ............. 147
5.4.8. Debate and conflict over technical issues and design decisions ............... 149
5.4.9. Development of client/user expectation (expectation management) ..... 152
5.4.10. Differences in perception of importance of certain issues ................. 155
5.4.11. Facilitation .................................................................. 156
5.5. Summary of findings ....................................................................... 158
  5.5.1. Lean elements ............................................................. 158
  5.5.2. Integration indicators .................................................... 160
  6.1. Case description ................................................................ 163
    6.1.1. About the key participants ........................................... 164
    6.1.2. Background ................................................................. 165
    6.1.3. Specific project challenges .......................................... 166
  6.2. The project organisation .................................................... 167
  6.3. Project delivery strategy .................................................... 167
    6.3.1. “The Five Big Ideas” .................................................. 168
    6.3.2. Project specific initiatives ......................................... 170
  6.4. Design to target cost ................................................................ 171
  6.5. The Last Planner System ................................................... 173
  6.6. Findings from the target value design process ..................................... 173
    6.6.1. Design developed in conformance with project budget ............... 173
    6.6.2. Higher level of detail in early design phases ....................... 175
    6.6.3. Sufficient feedback difficult to obtain ................................ 175
    6.6.4. Partners not equal – clear leadership taken ....................... 176
    6.6.5. Facilitation .................................................................. 176
    6.6.6. Engaged participants ..................................................... 178
    6.6.7. Change of participant roles and working processes ............... 179
    6.6.8. Reduced importance of cost data bases ............................. 180
    6.6.9. Set-based design processes ......................................... 180
    6.6.10. Collaborative design found time consuming .................... 181
    6.6.11. Authorities’ approval processes was a bottleneck ............... 182
    6.6.12. Controlling risk; a top priority in the supply chain ............. 183
    6.6.13. Divergent interpretations of project’s development ........... 184
    6.6.14. Interaction with other projects ..................................... 186
  6.7. Summary of findings ................................................................ 186
    6.7.1. Integration indicators ................................................... 187
7. Analysis and discussion ....................................................................... 191
  7.1. Research question 1: ................................................................ 191
    7.1.1. Who is the end customer in (lean) construction? ................. 192
    7.1.2. Is it possible to define end customer value? ....................... 196
    7.1.3. Is it possible to identify waste? ....................................... 201
    7.1.4. Purpose of design/construction integration ......................... 203
    7.1.5. Empirical findings ....................................................... 205
    7.1.6. Discussion .................................................................... 209
    7.1.7. Conclusion ................................................................. 216
  7.2. Research question 2 .................................................................. 216
7.2.1. Project value specification ................................................................. 217
7.2.2. Active client, user and stakeholder involvement .............................. 219
7.2.3. Decision and decision process transparency ..................................... 220
7.2.4. Transparency regarding value/waste consequences of design decisions 221
7.2.5. Management of design iteration processes ....................................... 223
7.2.6. Collaborative design with contractor/supplier involvement .............. 224
7.2.7. Commitment from project participants (including suppliers) ............. 226
7.2.8. Project team learning ....................................................................... 227
7.2.9. Discussion ...................................................................................... 228
7.2.10. Conclusion ..................................................................................... 229
8. Conclusions and reflections ...................................................................... 235
  8.1. Research question 1 .......................................................................... 235
  8.2. Research question 2 .......................................................................... 235
  8.3. Reflections on conclusions – thoughts on future research .................... 237
    8.3.1. The contribution of this research .................................................. 237
    8.3.2. Implications for practice ............................................................... 238
    8.3.3. Reflections on method and the limitations of the research ............. 239
    8.3.4. Suggestions for future research ................................................... 240
9. References ............................................................................................... 245
10. Appendices ............................................................................................ 269
  10.1. Appendix 1 ...................................................................................... 271
  10.2. Appendix 2 ...................................................................................... 275
  10.3. Appendix 3 ...................................................................................... 279
  10.4. Appendix 4 ...................................................................................... 285
Chapter 1

Introduction
1. Introduction

This chapter establishes the context of the thesis through a brief overview over the historical perspective of construction projects and their organisation. Characteristics of the construction industry will be introduced and the organisational separation of design and production activities will be considered with respect to their impact on construction project delivery.

The introduction of a Japanese manufacturing philosophy – ‘lean’ - to construction is studied in terms of its impact on setting an agenda for the development of project delivery systems for the Danish construction industry. The chapter concludes with outlining the purpose of the research.

1.1. A historical perspective of modern construction organisation

Construction has developed differently from country to country, both in terms of technology and organisation. If we restrict our perspective to modern times, construction can be seen as an activity that has been organised around projects. There have been regional differences and also differences between city and countryside. For example Swedish peasants long built what they needed themselves while construction in cities was a craft-based production structured around the services of the different trades whose organisation originated in the guilds of the Middle Ages (Ericson & Johansson 1994). More or less similar structures could be found in other parts of Scandinavia and Northern Europe.

A study of 19th century house building in Copenhagen (Engelmark 1983) discusses how the client of the building project was usually also the owner having the house built for himself, as his home, workshop etc. From the late 18th century this model gradually changed. Following the economical growth construction had become a lucrative business for the master craftsmen who invested parts of their profits in buildings that were not intended for their own use. These houses could either be rented out or sold. In addition to serving as investments these ‘design-build projects’ served to cope with the demand variations troubling the construction business. The master craftsman could level production through building for his own real estate investments in periods of low demand. This development towards a separation between client and owner/users was accelerated when it became possible to take up loans for house building.

During the 19th century the role of the architect developed and architects became that of the professional designer and project manager/agent that clients appointed to handle project delivery (Higgin & Jessop 1965). The architect was in control of design, the hiring of suppliers, craft and labour, and took care of organising the production regarding scheduling and site management. For many years house building in Denmark was relatively simple technology-wise. In the case of e.g. Copenhagen the building regulations were prescriptive in their nature and largely defined materials.

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5 An extreme example of this can be found when comparing ancient Egypt with Neolithic Denmark. The 3rd Dynasty of the Old Kingdom (2650-2575 BC) had technology, organisation and infrastructure to build large temples and the first pyramids. Meanwhile in Denmark local tribal societies erected simple dolmens as the technologically and organisationally most advanced construction projects.
In the 20th century, as construction went through a process of industrialisation, complexity increased in several respects. Regulation changed from prescribing ‘how to build’ to prescribing performance. Technologically building changed in terms of techniques, components and their interaction - a process that had started already during the industrial revolution and was accelerated throughout the 19th century (Satoh 1995). Environmental and functional needs developed and were commonly redefined. Fundamental responsibilities within the construction project organisation changed and the sector at large underwent major development. In different countries literature describing this historical development has been reviewed by different authors. Some examples discuss the development in the UK (e.g. Satoh 1995) and Sweden (e.g. Ericson & Johansson 1994, Brøchner et al. 2002). Hughes (1989), who reviewed a different body of literature, summarised that one outcome of the historical development was a split between design and construction and in between planning/pre-design and the design itself. Likewise design and project cost management became separated in terms of responsibility. From a Danish perspective an important development in the construction sector has been the increasing role of engineering consultant firms that in the postwar years have taken over many of the design, planning and client advisory assignments that large contractors (and in some cases large clients themselves) previously handled in-house (DR 2005).

Over the last decades of the 20th century emergence of ‘new’ organisations such as property developers, large project managing build-own-operate organisations and freelance consultants managing client project activity, have added to the organisational complexity and contributed to the increasing organisational ‘hierarchal distance’ (fragmentation) between client and end users.

1.2. Characteristics of construction

Based on a comprehensive literature review Thomassen (2004) suggests that construction is in general perceived to possess a number of organisational characteristics that appear to be of general character and shared by different local or national environments:

- activities organised in temporary project organisations;
- trade-based organisation of companies and individuals;
- labour-intensive;
- fragmentation deriving from the presence of many small and subcontracting firms;
- separation of design and coordination from production;
- highly independent activities;

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6 See the building codes and regulations for Copenhagen from 1856, 1871 and 1889 (reprinted in (Engelmark 1983)) that described to a very detailed level how a house should be built, and were revised along with the introduction of e.g. gas/water/sanitary installations, that followed the technological development in the second half of the 19th century. These regulations largely reflected construction practices that had been applied from the mid 19th century, and built on regulation principles that stayed in function until the years around World War II. - For a deeper introduction and discussion of the development in the building regulations of Copenhagen, see (Engelmark 1983). In the post-war years, governmental measures to facilitate industrialisation of construction led to the introduction of new regulation based performance criteria.
1. Introduction

- poor communication and coordination;
- ‘conservatism’, little change, a low level of learning and innovation, and consequently low improvement in productivity;
- competition on price and price reduction, not on innovativeness or optimisation with respect to client values;
- low levels of trust and high levels of conflicts; and
- a sector troubled by low quality, late delivery and overspending.

Thomassen (2004) cites Pries & Janszen (1995), who argued that building processes in Europe and the western countries look much alike, for support of the general/universal character of these findings. In addition to those highlighted by Thomassen, a number of others construction characteristics have been identified or suggested:

- Koskela (1992; 2000) suggests that construction, together with other sectors, is dominated by a biased transformation-orientated understanding of production with an under-emphasis on aspects of processes of flow and value;
- Meland (2000) shows how elements of insufficient design management correlate with failure to perform satisfactorily and to meet client expectations;
- cultural aspects peculiar to the construction industry at large and/or its different sublevels (Tavistock 1966; Ericson & Johansson 1994; Hancock 2000; Powell 2001; Riley & Clare-Brown 2001; Rooke et al. 2003; Jørgensen et al. 2004b; 2004c; Rooke et al. 2004; Ankrah & Langford 2005);
- site-specific immobility and long durability of products (e.g. Nam & Tatum 1988);
- extensive regulation (public and through sector agreements) regarding product performance, technical properties, contractual issues, financial issues, tendering procedures, health/safety etc. (e.g. Pries & Janszen 1995; Winch 2000);
- high sensitivity to fluctuations in the economical development;
- severe price-based competition where uniform demand makes it difficult for companies to follow a differentiation strategy (Pries & Janszen 1995).

Some of the characteristics listed by Thomassen are debated in other works and appear to be commonly held views of construction. However, the claim that construction suffers from a (relative to other industries) low level of innovation and poor development of productivity is challenged by Winch (2003). He argues that the use of Standard Industrial Classifications (SIC) for cross-sectoral comparisons with other industries tend to give a distorted picture due to inappropriateness of the measures compared. Winch rejects that a number of comparisons of construction with the motor vehicle industry have served with a true and fair benchmark for construction performance. The message by Winch is that researchers should be careful when making cross-sectoral comparisons and that such should not weigh key numbers and figures against one another without considering context.

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7 However, it should be noticed that in addition to many similarities, a large number of differences also exist between the national construction sectors. An example could be differences in the ‘power’ and influence held by architects in comparison to that of e.g. contractors. Such minor differences between national construction sectors may have large impact on the way these work. A discussion of similarities between large European construction sectors is provided by Winch (2000).
1.3. Construction – a criticised sector

The construction sector has long been blamed for poor performance on a number of parameters; cost level and productivity development, innovation, project completion times, compliance with deadlines, amount of defects and deficiencies, level of rework, customer satisfaction, unsatisfactory records of health and safety, etc. Throughout the postwar period many different initiatives have been launched with the aim of stimulating development and change in construction, in some case through public works or in the form of governmentally supported development programmes while others have been driven by the industry itself or have been organised as coordinated efforts between government, industry (and sometimes major stakeholders as e.g. clients and users). Some of these initiatives have focused on the products, others at construction processes while a third group has aimed at both product and process (e.g. development of element-based industrial building systems). Some initiatives were targeted to the macro level (industry and market) while others have addressed the micro level of companies, supply chains and individual construction projects.

Some of these initiatives have been largely political: setting an agenda of change, e.g. through urging (or forcing) stakeholders to introduce initiatives themselves. Often the proclaimed purpose has been to learn from other industries and change construction for the better through adoption of practices or technologies successfully applied elsewhere, typically manufacturing (e.g. the motor vehicle industry).

In the 1990s the construction debate of e.g. Denmark, the UK and much of the industrialised world devoted much attention to a number of approaches and concepts that were known from manufacturing where they were already established in industry and management debate. Among these were ‘total quality management’ (TQM), partnership relations, ‘business process reengineering’ (BPR), ‘supply chain management’ and ‘lean’. Of all of these innovations ‘lean’ has been the most heavily promoted in the Danish construction sector.

It should be noted that the debate on changing construction through adoption of management innovations from manufacturing industries has been widely one-sided in terms of promotion while research and publications critical to such agendas have been largely ignored (Green 2002; Green & May 2003).

1.4. ‘Lean’ – a Japanese management innovation

What in recent decades appears to be the production philosophy most heavily promoted (not least when considering its tenacity) and introduced in several business sectors was ‘lean’ - an approach which Womack, Jones & Roos (1990) presented as the means through which Japan’s largest motor vehicle company Toyota had “revolutionised car manufacturing” in terms of productivity, quality, product development etc. In their international bestselling business book ‘The Machine That

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8 Based on data from the Danish Building Research Institute Thomassen (2004) illustrates how postwar construction in Denmark has experienced productivity gains negligible in comparison to that of other sectors.
10 In relation to design management at construction projects in Norway, reasons for failure to meet customer expectations and demand have been elaborately examined by Meland (2000).
11 Bertelsen & Nielsen (1999) provide an overview of Danish initiatives of the 1990s aimed at developing construction productivity. Based on cases from some of these development initiatives Clausen (2002) studied construction innovation processes. Drawing on findings from one of these programmes Thomassen (2004) studied the economical organisation of building projects, concluding that the wider contextual business framework often discourages organisational changes on micro level.
1. Introduction

By Bo Jørgensen (2006)

*Changed The World* the authors claimed that this Japanese approach was applicable far beyond car manufacturing and that it would radically change industries in the rest of the world in the same way as it (according to the authors) had already changed first Japan and afterwards the international motor vehicle industry. Following up their arguments this claim was later elaborated by Womack & Jones (1996; 2003) in *“Lean Thinking”* where construction was pointed out as an example of a business sector where the principles promoted offered substantial improvement. In the book this was illustrated by a practical, though strongly simplified, example.

‘Lean production’ - as Womack *et al.* (1990)\(^{12}\) called the approach they promoted – built on a philosophy of systematically *eliminating waste*, i.e. every activity, process or disposition not adding *value for the end customer*. It joined the long row of (commonly related) management innovations that were adopted from Japan for application in the West (Lilrank 1995). However, it stands out from most others because 15 years after *‘The Machine That Changed The World’* lean continues to be high on the agenda of popular management debate in e.g. Denmark. Anecdotal evidence suggests that this is a remarkably long time for a management innovation to stay fashionable.\(^{13}\) Perceptions and definitions of ‘lean’ will be discussed further in Chapter III.

1.4.1. ‘Lean’ in construction

Koskela (1992) studied the philosophy of lean production and discussed its application to construction. The following year the First International Workshop on Lean Construction was held and The International Group for Lean Construction (IGLC) formed, though its current name was not adopted before 1995. IGLC has never been set up as a formal organisation but has hitherto existed as a loosely organised network/platform open for all researchers and practitioners searching for improved ways of managing construction. The group organises an annual conference (open for participation by anyone interested) which has been steadily growing in number of participants and contributions. Since the formation of the IGLC a number of organisations, institutions and independent consultants have established themselves (locally and internationally) as producers and providers of knowledge, and a growing number of construction companies have adopted different practices, all under the label ‘lean construction’ (Jørgensen *et al.* 2005). - See Chapter III for a further introduction to lean construction and the broader lean construction debate.

1.5. Lean construction adopted as strategy for improvement

In several countries, e.g. in Denmark and UK, ‘lean construction’ was embraced in the construction improvement debate and promoted as a ‘new understanding of the construction process’ that could or would bring substantial improvements of productivity, profitability and stakeholder satisfaction. A report by the Danish Academy of Technical Sciences (ATV 1999) argued the need for an industrialised reorganisation of construction design and production processes; ‘lean production’ was promoted together with other industrial approaches fashionable at that time (‘Business

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\(^{12}\) The term ‘lean production’ was originally coined by John Krafčik (1988) but was popularised through the release of (Womack *et al.* 1990).

\(^{13}\) Characteristics of management fashions have been discussed by Abrahamson (1996) and Kieser (1997). Kieser specifically emphasised lean production as an example of a management fashion that had been designed for becoming a fashion.
Process Reengineering’, ‘Just-In-Time’, ‘Supply Chain Management’ and initiatives for ‘partnering’). The popularity of ‘lean construction’ was not an exclusive Danish phenomenon and the (international) attention increased with the publication of the British “Egan report” *Rethinking Construction* (DETR 1998), popularly named after the chairman of the *Construction Task Force* that prepared the report. This publication promoted “Lean Thinking in construction”\textsuperscript{14} as an approach that *should* be adopted for bringing sustaining performance improvement for the UK construction industry. The substantial argument for this being an advantageous move was the claim that the ‘Lean Thinking’ approach to have delivered large improvements in manufacturing, in particular the motor vehicle industry, and where already applied in construction. If viewed objectively the report could hardly be considered as anything more than a discussion paper. It lacked any research basis and had been authored by representatives of major client organisations (with special interests in the course of development of the construction industry) as the chairman Sir John Egan, himself chief executive of The British Airport Authorities (BAA). The report was nevertheless very successful in setting an agenda of adopting lean construction. The report did not explicitly define what was represented by the reference to ‘Lean Thinking in construction’. ‘Lean thinking’ was superficially defined as “describing the core principles underlying the Toyota Production System” that was however not described in any detail.

Green & May (2005) subsequently interviewed the individual members of the task force revealing that these promoters of “Lean Thinking in construction” did not share a common definition of ‘lean’ or of ‘lean construction’, nor did they present the same perception of what it implied.

Whatever the reason for the lack of consensus on glossary among Sir John Egan and his fellow authors, it is not surprising that people searching for information on lean construction end up reaching different definitions and perceptions. While there is no universal definition of lean construction, a number of different definitions have been brought forward by different authors, and there appears to be a diverse focus in application of lean construction in different local construction environments (Jørgensen *et al*. 2005). - This plurality in definition is examined and discussed in Chapter 3.

1.5.1. ‘Lean design’

Womack *et al*. (1990) emphasised the importance of the holistic lean approach in the design as well as in product development processes. When introducing ‘the new production philosophy to construction’ Koskela (1992) similarly highlighted design and product development as important issues for improving the efficiency of construction delivery. Approaching design from the overall holistic perspective, as promoted by commonly cited literature on ‘lean’ philosophy/production (as Clark *et al*. 1987; Ohno 1988; Shingo 1988; Clark & Fujimoto 1990; Womack *et al*. 1990), has nevertheless received relatively minor attention within construction publications labelled ‘lean’. This is remarkable when considering design’s huge impact on

\textsuperscript{14} The consistent use of the term “lean thinking” in the report is remarkable. For support of the recommendations made, the authors highlight an example of a Californian contractor applying ‘lean thinking’ and using the Last Planner System. The term ‘lean construction’ appears only when the authors refer to the Lean Construction Institute. This observation is interesting in the light that one of the task force members was professor Daniel Jones who had recently published the (popular) management book “*Lean Thinking; banish waste and create wealth in your corporation*” co-authored with James P. Womack (Womack & Jones 1996).
subsequent production processes and the possibilities for efficient production planning and control - issues that have dominated work labelled ‘lean construction’. A main reason behind this prioritising of focus may be found in the huge challenge of approaching design issues with regard to all their subsequent impacts on the life and value connected to the building procured. It does, however, indicate that the existing contractual division of design and production tasks has a vital impact on the incentives for research and development since dominating stakeholders have special interests in some construction (sub-)processes more than others. When an organisation decides to adopt an innovation (as e.g. lean construction) it is natural that the situation, position and interests of the adopter are reflected in the choice/selection of the ideas (e.g. Rogers 2003). With strong contractor involvement in the lean construction movement a biased emphasis on production issues is not unnatural (Jørgensen et al. 2005).

Similar to ‘lean construction’, ‘lean design’ does not have a clear common definition. ‘Lean design’ has been used for a variety of work applying elements of the lean philosophy to (construction) design or for applying known lean construction tools as e.g. the Last Planner System of Production Control to construction design management. Some interesting contributions have addressed the design issues mainly from the perspective of minimising negative iteration in design (e.g. Huovila et al. 1994; Koskela et al. 1997; Hammond et al. 2000) or discussed the application of product development techniques developed in manufacturing for construction design (e.g. Huovila et al. 1994; Formoso et al. 2002c). Other work has discussed the coordination of design and site activities through application of visualisation tools (e.g. Ballard & Kunz 2004; Tan et al. 2003). In the overall perspective integrating production process planning already early in the design phases, where many production preconditions are established, remain only vaguely addressed. There has, however, been a gradual development towards stronger representation of design issues in construction debate and publications addressing upstream supply chain issues from a lean perspective. Studies of the possibilities for applying ‘design to target cost’ procedures to construction by Ballard & Reiser (2004) and Granja et al. (2005) are recent examples of the few lean construction labelled publications approaching design/construction integration.

1.6. An agenda for design/construction integration

‘Integration’ has in different ways been high on the agenda of the current construction debate. As mentioned above, a typical characteristic of construction is the separation and commonly also fragmentation between design and production, which in general is referred to as something problematic (Bouchlaghem et al. 2004; Baiden et al. 2006) and publications have often argued that design and construction (and services) should, in one way or another, become better integrated (e.g. Brandon & Powell 1984; Hughes 1989; Bröchner 1990; Koskela 2000; Anumba et al. 2000; Austin et al. 2001; Gray & Hughes 2001; Emmitt 2002; Bouchlaghem et al. 2004; Kimmance et al. 2004). Although integration and other change initiatives have been on the agenda for a long time and though the industry frequently adopts new terminology for the ongoing debate on improving construction it has been argued that very little has changed structurally (Cox & Ireland 2002).

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15 See e.g. (Ballard 1994) and/or (2000a).
The ongoing discussion on construction design/production integration has been approached from different perspectives. Some examples are:

- **Vertical integration of the supply chain and/or integration of project management structures**: e.g. the design-build model for project organisation can be seen as an integrative procedure;
- **Inter-organisational integration for the strengthening of the framework for cooperation**: e.g. long-term cooperation agreements, partnering initiatives etc.;
- **Integration of business processes**: e.g. initiatives for integrating procurement and operation through arrangements of BOT (Build, Operate, Transfer) or BOOT (Build, Own, Operate, Transfer), designing for facilities management etc.
- **Integration around products and assembly processes**: e.g. concepts for ‘systems supplies’ where individual suppliers deliver entire systems for a construction project;
- **Team integration**: initiatives (inter-/intra-organisational and social) for motivating construction project participants to working collaboratively;
- **Integration around specific processes for improved coordination and more efficient handoffs**: e.g. the ‘design for assembly’ approach;
- **Integration around information systems**: e.g. IT systems and shared platforms where information produced upstream can be directly transferred for use in downstream processes in the form in which it was produced.

Significant examples of contributions to the wider debate on aspects of construction integration are (Latham 1994), (ATV 1999), and (BBM 2000) – works that appears to have greatly influenced recent years’ political focus on the development of the construction industry in the UK and Denmark.

As will be discussed in Chapter 3, the lean philosophy principally addresses several of the perspectives mentioned above, while the debate on its application to the built environment has focused mostly on the two last.16

This thesis will approach the theme of design/construction integration from the perspective of de-fragmenting the division of design and assembly processes and apply the lean philosophy to the project delivery process encompassing both design and assembly. – As will be further motivated at the end of Chapter 3, the choice of

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16 In this respect the Danish lean construction debate is unique since team integration (the third bullet point from the bottom) has received much attention. Process facilitation was an important element in the first adopter’s concept for lean construction (see Jørgensen et al. 2004b; 2004c) and has been the very core of reported initiatives labelled ‘lean design’ or ‘lean design management’ (see Emmitt et al. 2004; 2005). An interesting observation is that despite the lean philosophy of collaboration being very concerned with the formal relations in the supply chain (Ohno 1988; Womack et al. 1990; Womack & Jones 1996; 2003; Cooper & Slagmulder 1997; 1999) the adoption of lean construction does not seem to have affected these and contracts are conceptually the same regardless of whether they are to support a ‘lean’ cooperation or not. Locally this delimitation has been promoted by a very visible and passionately engaged consultant who played a key role as change agent introducing lean construction, publicly promoting some of the principles and tools, while also educating and supervising practitioners. In teaching and debate this consultant has explicitly promoted that lean construction should focus on processes and be separated from the contractual issues. In this regard lean construction has been promoted as a ‘framework for good and efficient collaboration in spite of the contractual settings’ (Jørgensen et al. 2004b). – For a discussion on the Danish perception of lean construction, see (Jørgensen et al. 2005).
this particular focus is motivated by the understanding of lean design and lean construction as suggested by the literature review.

1.6.1.1. Understanding of the term ‘integration’

Based on a comprehensive literature review, Baiden, Price & Dainty (2006) suggest that integration can be considered as “the merging of different disciplines or organisations with different goals, needs and cultures into a cohesive and mutually supporting unit”, and that integration in construction describes the introduction of “working practices, methods and behaviours that create a culture of efficient and effective collaboration by individuals and organisations”. Research based on empirical findings from the UK did not support that ‘seamless operation’ is a fundamental requirement of integrated team performance (Baiden et al. 2006). The findings of this research indicate that the theme of integrating construction design and production processes from a lean perspective can be approached inter-organisationally and does not necessarily require a vertically integrated supply chain.

1.7. Gap in knowledge

There has to date been little documented research into the application of the lean philosophy to design and construction, especially when considering the width and complexity of the issue and if comparing to the economical value of the throughput of the business systems addressed.

As mentioned above, (lean) design issues have been addressed to a far lesser extent than that of production issues. Issues of integration of design and production from a ‘lean’ perspective are currently being addressed but are not yet thoroughly and systematically investigated.

This can be summarised as follows:

- ‘Lean’ design and construction is on the agenda of developing the construction sector in Denmark and abroad;
- Design/production integration is promoted in the ‘lean’ philosophy and in the debate on construction business development;
- Integrated application of the ‘lean’ philosophy to design and construction is pursued by some construction organisations in Denmark and abroad;
- There is little documented knowledge about holistic application of the ‘lean’ philosophy from the entire construction project perspective including both design and construction.

This research will aim at addressing this gap in knowledge.

1.8. Purpose of the research

The purpose of this research is to contribute to knowledge and insight about lean construction and lean design from the perspective of integrating or de-fragmenting design and production processes of construction delivery.

1.8.1. Research questions

When considering whether to pursue an agenda promoting integration between lean construction and lean design, the most basic piece of information needed is whether the lean philosophy is appropriate for understanding design/construction integration. This prompts the first research question:
1.8.1.1. **Research question 1:**

*Is the lean philosophy appropriate as a means for pursuing integration of construction design and production processes?*

If deciding to pursue a strategy of de-fragmenting design/construction through lean design and lean construction, it is crucial to identify processes, methods and/or issues that are crucial for achieving a higher degree of design/construction integration. This prompts the second research question:

1.8.1.2. **Research question 2:**

*Which processes and/or methods and/or issues are crucial or critical for integrating construction design and production from a perspective of the lean philosophy?*

1.9. **Structure of dissertation**

The sequential structuring of the first three chapters requires a comment. The structure of the thesis reflects a conscious choice of organising the work so that it is easy for the reader to follow. Therefore the introduction, Chapter 1, outlines the research and the thesis. Research strategy and method are dealt with together in Chapter 2, while in Chapter 3 the field of ‘lean’ and its application to construction is investigated and the framework of working definitions is deducted.

The chapters 4-6 cover the empirical part of the research. Each describes a case study and related empirical findings. In Chapter 7 the findings and results are analysed and discussed. The conclusions are summarised in Chapter 8 which is closed with some reflections on the outcome of this study and recommendations for future research. A list of references is presented in Chapter 9 and the appendixes in Chapter 10.

To the experience of the author the typical doctoral thesis is structured so that it first a) describes what is already known, b) subsequently identifies a gap of knowledge, and eventually c) presents a research question. Finally d) a research method is adopted and the actual investigation carried out. However, for this dissertation a rigorous application of this structure would have an undesirable impact on the readability of the work. The *existing body of knowledge* within the field (‘lean design/construction’) had not been discussed or evaluated to a deep level prior to this investigation - which among other things implied that no obvious definitions of ‘lean construction’ and ‘lean design’ was available. The establishing of a terminology was a research activity in its own respect and thus subject to methodological considerations in the context of the purpose of the research. Therefore this thesis introduces the research strategy and methods prior to the description of the ‘lean’ philosophy and its application to construction design and production. The need for establishing working definitions derived from the research questions - that were themselves shaped by the iterative process of developing an understanding of ‘lean’ in design and construction. It would have been possible to structure the dissertation according to the a-b-c-d sequence as described above, but this would not have enhanced the readability in terms of establishing a transparent overview of the research, its approach and the choices from which the investigation was conducted.
1. Introduction

1.9.1. A few comments on terminology
Much of the literature in the area of ‘lean’ makes extensive use of Japanese terms and sometimes cliquish language. Obvious examples are *muda* (Japanese for waste), *kaizen* (Japanese term used for referring to continuous improvement), *gemba* (Japanese for shop floor), and *poka-yoke* (defect-detecting system) 17. Some terms were highly popularised throughout the 1980s and 1990s when Japanese management concepts became hot management fashion in USA, Europe and other Western countries.

With the exception of the terms including the word *lean*, this thesis will, as far as possible, abstain from using such language unless special circumstances make it necessary.

There are two reasons for this choice of terminology employment:

- **Unambiguousness**: Differences exist in the meanings ascribed to lean terms and Japanese words.
- **Readability**: One purpose of this thesis is to provide clarity over the topic studied, to demystify rather than contribute to mystification.

Regarding the first point, it is illustrated in Chapter 3 that different authors have ascribed different meanings to the term ‘lean’. Discussing the theme of lean and how it can be understood in terms of practical application from the perspective of design/construction integration becomes unnecessarily complicated if operating with ambiguous terminology where plain English is sufficient.

17 *Poka-yoke* (in some publications ‘poke-yoke’) are automatic inspection methods to detect production defects. For a discussion on poka-yoke methods, see (Shingo 1989).

It should be noticed that poka-yoke appears to be commonly mistranslated to ‘fool-proofing/mistake proofing devices’ (pointed out by e.g. Berggren already in 1990 citing early publications of Shingo (Berggren 1990 p. 64) but the mistaken translation appears to, if not dominate, be very common in western publications on ‘lean’).
Chapter 2

Research strategy and method
2. Research strategy and method

This chapter will provide an overview over the strategy and action through which this study is undertaken. The considerations behind the research strategy will be introduced and the choice of research methods argued for. Finally the case study methodology and data collection techniques will be introduced.

2.1. Identifying information for answering the research questions

For answering the research questions one will need to clarify from which understanding of ‘lean construction’ and ‘lean design’ that the research will be directed. As mentioned in the introduction – and as will be discussed in the next chapter (Chapter 3) – varying definitions of ‘lean’ in design and construction co-exist, and for the answering of the research questions these will need further investigation. It is also necessary to clarify how ‘integration’ will be understood in the context of lean construction and lean design. A working definition of design/construction integration will be introduced, following that of ‘lean construction’ and ‘lean design’.

2.2. Research strategy

A brief view over publications discussing applied lean construction/design (e.g. proceedings from the annual conferences of the International Group for Lean Construction, IGLC) reveals a rich variety of initiatives that are all labelled ‘lean construction’ and represent, not only different emphases of individual aspects but also different perceptions of lean construction. A comparative study with examples from Denmark and California has illustrated examples of diverse focus in the application of lean construction and highlighted the probability that the term ‘lean construction’, to various extents develops local meaning (Jørgensen et al. 2005). Studying publications it becomes evident that a highly abstract ‘lean philosophy’ of optimising value and minimising waste is a very different matter from putting it all into practice, as will be discussed in this thesis.

Practical lean construction draws on inspiration from the philosophy rather than reflects it (Koskela et al. 2002). Because of this a purely theoretical study of lean design/construction would be of little relevance to the construction sector and to construction management research, given that construction management is regarded as a field of application (an understanding promoted by Hughes (1997; 1999)). Another argument for studying both theory and practice is provided by Cook & Brown (1999) who suggested the bridging of epistemologies of organisational knowledge and organisational knowing, where the latter represents knowing (explicit and tacit on both individual and group level) into action. If accepting this ‘bridged epistemology’, organisational concepts such as the lean philosophy must be understood through the two dimensions: knowledge and practical action. For achieving a broader understanding of ‘lean construction/design’ it is insufficient to study only literature, and similarly insufficient to study only practice. This calls for a study based on both literature and exploratory case studies conducted through an ethnographic approach (methods discussed below).

Other strategies and sources for data collection such as e.g. experiments, historical studies and archival analyses that are commonly applied in explorative research (Yin
1994; Andersen 1999) have not been applied for this research, since such methods were either impossible to conduct within the framework of this investigation (where the researcher did not possess control over the events studied), or they were deemed unlikely to contribute substantially to answering the research questions.

2.2.1. Focus and scope of research – limitations

The study will restrict its focus to the construction of buildings. There are a number of reasons why this is considered necessary of which the two most important are a) that the existing body of literature and documented studies on lean construction appear to concentrate on construction of buildings while other structures as e.g. bridges, tunnels etc. have received little attention; and b) that the researcher could get access to Danish building projects where lean design and construction was applied, while no civil construction works executed through application of lean design/construction concepts were available. This does not necessarily imply that findings are irrelevant for construction of e.g. bridges and roads etc. but this is a question that will not be pursued in this dissertation.

2.3. Literature studies – defining focus

The extensive body of previous work relevant for further examination of the application of process-orientated approaches to construction delivery, as well as into issues of design/production integration in general, is a challenge to research of this topic. Furthermore the multidisciplinary nature of the three issues central to this thesis - (construction) design, production, and organisation - adds to the challenge. The topic of this research falls within the very broad field construction management which is difficult to define as its influences are very diverse (Hughes 1997; 1999). A wide range of issues, academic disciplines and research areas can be argued to be of high relevance for this thesis, thus presenting a distinct challenge for the literature used. This presents researchers with a challenge regarding the choice of focus: it is difficult to imagine how anyone could carry out serious research based on such a wide variety of academic disciplines, in such a way that it would be recognised by researchers in those disciplines (Hughes 2004). On the other hand it is difficult to imagine how applicable research into a broad and complex theme as that of the present thesis could be accomplished in complete ignorance to research and findings within the following areas and disciplines related to:

- process-orientated value/waste focused production philosophy (‘lean’);
- Supply Chain Management;
- (construction) design disciplines (e.g. architectural management and architectural technology);
- construction production management;
- sociology (e.g. organisational culture);
- innovation and diffusion studies;
- economics, management and administration, and;
- disciplines of the social sciences concerned with processes of decision making, co-operation etc.

Either way the research may potentially be exposed to criticism. If taking a broad approach and incorporating work from a wider number of disciplines the academic depth can be questioned by researchers within these different disciplines. If applying a very narrow focus taking into account previous work exclusively from one or two
academic disciplines, the research will inevitably be questionable and of little academic and practical value.

One approach occasionally applied is to concentrate on the extensive body of previous research within the already very broad field of construction management. Such research strategy however rests on the assumption that construction management can be considered a field or a discipline in its own right. This assumption contradicts the fact that the construction management domain does not have its own research techniques and theories. As construction is fundamentally a sub-set of human experience, rather than a completely separate phenomenon, this too would be an approach exposed to criticism. It can be argued that construction rests on a rich source of problems and data which do not necessarily preclude one or another discipline. Along with education (that needs a certain degree of specialisation to meet the requirements of practical application), professions may need to define and defend boundaries in a way that research does not (Hughes 1997; 1999).

Acknowledging this multi-disciplinary nature of the construction management domain the question should therefore not be whether to restrict the literature search to a single field of academic publications, rather it is a matter of how to research cross-disciplinarily while avoiding falling into non-disciplinarity.

Another argument for choosing a broader perspective to identifying which of the previous works that are the most relevant (from a variety of academic disciplines) is rooted in the very body of the existing construction organisation/management research. Though there may be some emerging directions of theory development that are unique to construction management, or construction economics, most research in this area builds upon theoretical models developed elsewhere, primarily in the social sciences (Hughes 2001). There is no world-wide overview of comprehensive works of research within construction management but in general they appear to be drawing on works from a large variety of fields. In a survey (based on 97 responses with a heavy bias towards the UK) on doctoral research projects within the field of the built environment, Hughes (2003; 2004) identifies a wide range of different academic disciplines, research areas and approaches through which the individual investigations are conducted. The survey emphasises two circumstances: a) that individual works generally draw on a multiplicity of scientific disciplines, and b) that typically several scientific disciplines form the academic basis of the research projects. The survey revealed that 95 respondents mentioned in total 58 different academic disciplines as the basis of their research, with management, economics, information technology, sociology and psychology being those most frequently mentioned. This survey strongly indicates that construction doctoral research (which is very strongly represented among comprehensive in-depth studies of construction issues) generally is extensively diverse regarding academic and scientific basis. Therefore future research cannot build on previous research on construction management exclusively without violating the principle tracing the antecedents of the adopted theory and principles back upstream as far as possible. By not doing so, one risks that construction research eventually directs into a course of independently developing theory that may long have been formulated, tested and discussed in the wider academic community (Hughes 1997; 1999).

This problem is highlighted by Bresnen & Marshall (2001) arguing that the search for a ‘best practice’ can easily lead to a tendency to discount or ignore some of the inherent problems and limitations of new approaches developed in different contexts, or of the conditions necessary for their application. Bresnen & Marshall warn that the
status of construction management as a distinct discipline and practice can lead to selective filtering and adaptation of ideas and approaches in ways that reflect the industry’s own particular assumptions about management knowledge.

From this derives a third argument for adopting a multi-disciplinary approach in conjunction with methods and theories from more ‘basic’ academic disciplines. Doing so increases the relevance of construction research to research conducted within other fields. If succeeding in making construction research draw increased attention from other research fields and different academic disciplines, construction research will be more studied and discussed than before, thus improving the quality of its evaluation while substantially increasing broader academic feedback for the benefit of future research into the built environment.

If accepting that the above list of topics/categories as representing those most relevant to the present research, it immediately follows that the process of identifying the actual focus is far from complete. Every year several thousands of articles, books, conference papers, theses and reports of potential relevance are published within these areas and therefore the need to strictly prioritise the search within this material is obvious. It is thus critical to identify appropriate criteria for the process of searching and selecting individual publications for support of the scientific work. In the present case this process inevitably will have to reflect the key issues dealt with:

- the ‘lean’ philosophy and its application to construction;
- design/production integration, and;
- process-orientated construction design and project management.

These themes provide the starting point for identifying a gap in knowledge and subsequently formulate appropriate research questions.

Selecting literature is, however, afflicted with several other concerns and considerations regarding the relative weighting of available material in respect to their ‘solidity’ and applicability, which varies considerably within each field/category. Specifically within the area of ‘lean design/construction’ this circumstance provides significant challenges that deserve extra attention as this issue is in the very core of what is being investigated while also being a theme in which relatively little research has been published. The hitherto modest research contribution is significant when considering the width of the topic and that it is essentially based on a philosophy that in principal addresses every aspect of construction delivery and the organisations involved. That little research has been published under the label ‘lean design/construction’ does however not imply that little research has been published within the areas addressed by specific lean initiatives or within the individual elements of the lean philosophy. Lean construction contains many elements from other approaches, systems and concepts of which many have been subject to extensive investigation over several decades and through several academic disciplines, methods and approaches. If understanding the lean construction area as containing a number of sub-areas, it would thus be a mistake to conclude that little previous research is available, but there has been little published research into wider system perspectives of construction services delivered in accordance with the philosophy of ‘lean construction’. Especially contextual issues seem to be weakly represented in publications (research and other) on lean construction (Green 1999a; 2002; Green & May 2003; 2005).
2.3.1. Judging and weighting publications: academic, debate, opinion
As will be discussed further in Chapter 3, no common definition of lean construction exists. Furthermore, if dividing the publications labelled ‘lean design/construction’ under three categories ‘academic’, ‘debate’, and ‘opinion’ there appears to be an imbalance in their numbers for the benefit of the two latter.
It can be argued that it in principle is preferable for research to develop its arguments under a citation approach considering only academic work as e.g. articles from recognised peer-reviewed research journals, other theses etc. The field of lean construction (in many respects still in its infancy) is, however, discussed mostly in a large selection of conference papers of varying academic relevance. In this thesis, limiting the view so that it would not recognise and consider this important contribution to the ongoing lean construction debate, would provide a relatively poor basis for relating to the overall theme of ‘lean’ in construction design and production, and for discussing trends and development within the area. From these considerations, conference papers of the International Group for Lean Construction and popular titles - that play a key role in shaping the lean diffusion and implementation debate – will be given a role in the following discussion that is more prominent than one would otherwise expect.

As mentioned in the above, it was considered important for this research to study also concrete initiatives and practical efforts aimed at integrating lean design and lean construction. The intention was to use ethnographic research techniques and qualitative methods (e.g. non-participant observation, interviews, focus groups etc.) to collect empirical data that reflected the actual application in the larger organisational context.

2.4. Case study: design and method
An important element of the research strategy was to follow the case projects and collect data over longer periods of time to be able to study the design processes in relation to production aspects. In relation to a Ph.D. schedule of three years from start to completion, large construction projects are typically longer in duration. Running a pilot study prior to actual case studies (as suggested by e.g. Yin, 1994) was therefore not possible. Having to start all over with new case studies - if realising that the initial data collection strategy was failing - would also be highly problematic. It was thus vital that data collection would be efficient from the very beginning of each case study.

2.4.1. Multiple case studies
From the outset of the research project it was decided to adopt a multiple case strategy for the collection of empirical data in order to explore the application of lean approaches to design/production integration. Case studies are advantageous for investigating “how” or “why” questions (Yin 1994), as in this research where case studies were to provide empirical evidence of how construction organisations approach the theme of design/production integration through application of the ‘lean’

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18 The researcher’s personal experiences from a previous study, (Jørgensen & Geert-Jensen 2002), into implementation of a lean construction in a Danish contractor organisation did however contribute substantially to the development of the research strategy. This study was to some extent considered as a pilot study for the research.
philosophy. There were several reasons for this decision (methodological and practical), of which the main were:

- The scope for ensuring validity would benefit from the research not being dependent on a single case project being sufficiently representative. This aspect was crucial since there appeared to be no consensus regarding a definition of ‘lean’ in construction design and production, nor a uniform model for its application.
- In relation to the research questions there was no indication that any potential case project could provide a critical, extreme or unique case that could have prompted a single case study, as discussed by Yin (1994).
- Multiple cases would make the research less dependent on the course and development of a single project and continuous possibilities for studying it.\(^{19}\)
- By studying more than one case project it would be possible to broaden the perspective beyond the national context of Denmark and the single Danish contractor to whose projects the researcher (when the investigation commenced in 2003) could get access to study practical application of a lean approach to design phases.

While the general picture spoke in favour of a research design with multiple case studies, this approach did however also have some disadvantages. Every case study was very time consuming, and being only one researcher having to follow several case projects in parallel inevitably implied that the data collection from the individual case study was less profound than what could have been achieved under a single-case approach.

The original intention was to study four projects but due to cancellations and project postponements, only three case studies were eventually executed. All in all it was however possible to gather appropriate data from the case projects and the advantages of the multiple methods approach were found to clearly have exceeded its disadvantages.

For the design of the individual case study, see below.

### 2.4.2. Data collection

A study of lean construction implementation from a change management perspective (Jørgensen & Geert-Jensen 2002) had revealed that individuals in the Danish construction industry had very different interpretations of the same lean initiative (Jørgensen et al. 2004b; 2004c). When the research strategy was developed in 2003 it was thus considered likely that within the few accessible case projects’ the application of lean philosophy/ideas and methods/tools was likely to be of limited extent and represent to some degree different interpretations of lean construction. It was also clear that lean application in the case projects could easily change over time as the organisations involved gained more experience and developed their approach(es). It was thus very difficult to forecast exactly what was going to be observed. Since the research was partly grounded in the outcome of the case studies it was critical that the data collection was profound enough to ensure sufficient material to work with. Given these circumstances it was important for the data collection strategy to be ‘robust’ in the sense of possessing a high tolerance to changing conditions. In this

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\(^{19}\) Choosing of this strategy was rewarded when case projects become postponed, delayed, or rescheduled for the disadvantage of the data collection.
situation it was decided to apply a strategy of collecting data from multiple sources through multiple methods. The methods chosen were:

1. Non-participant observations of design meetings (and when possible other project meetings) of the projects studied;
2. Analysis of project material (tendering and bidding documents, meeting minutes, correspondence etc.) accessible;
3. Qualitative interviews with project participants (an element of the case study strategy which was later revised, see below).

These methods were selected to complement each other and to provide some degree of flexibility in the research dependent on the development of projects, while also allowing for addressing three different data sources (observations, project material and interviews). Multiple data sources provide greatly improved possibilities for checking for biases, simple errors in the data material and other factors that may severely weaken research based on a single data source. With this strategy for collecting data it was possible to analyse the empirical material through a process of ‘triangulation’ of data sources, thus strengthening the scope for ensuring validity of the case studies (Yin 1994). This data collection strategy was expected to be suitable for studying design/construction integration issues, including those that could prove difficult to study through only one kind of data collected.

From the outset of the research it was a conscious decision not to use questionnaires for data collection. According to the researcher’s previous experience, questionnaires were deemed to be a very inefficient way of gathering data at construction projects since the response rate is usually very low. Besides, for questionnaires to be efficient for data collection these must necessarily be designed from knowledge and understanding of what kind of information is searched for. Questionnaires can then provide feedback on questions of ‘what’ and ‘how’ while more open-ended questions of ‘why’ are much harder to investigate (Yin 1994). All in all this method was considered inappropriate for collecting data for this research. The original strategy was therefore to concentrate on collecting data through non-participant observation, project documents and interviews. Due to development of the individual case studies the data collection strategy was slightly revised in terms of the application of collection methods, and also questionnaires were introduced (see below).

Following an introduction of the measures taken to ensure satisfactory quality of the case studies, the applied data collection methods will be further introduced in terms of approaches and methods, and how these were adapted during the progress of the case studies.

**2.4.3. Establishing quality in case studies**

According to Yin (1994), four tests are commonly used to establish the quality of empirical research: *construct validity, internal validity, external validity, and reliability*. The intention here is not to repeat the arguments for conducting such tests but only to verify how these tests have been applied to the case study design, data collection and analysis:

- **Construct validity**: The essence of construct validity is to establish correct operational measures for studying the phenomena that the case study is meant to investigate. A case study tactic for ensuring construct validity proposed by
Yin (1994) is to a) use multiple sources of evidence, b) establish chain of evidence (enabling the reader to follow the derivation of evidence from research question to conclusion), and c) have key informants review draft case study report. The two first measures were applied for the case studies of the present research.20

- **Internal validity**: Internal validity is about proving the correctness of the connection between cause and effect concluded by the study. Ensuring internal validity is crucial to explanatory case studies but is inapplicable to descriptive or explorative studies (as the present).

- **External validity**: This is about establishing the domain to which the findings of a case study can be generalised beyond the immediate case study. Since construction constitutes an enormous field representing an extremely wide range of different activities with enormous variability in volume, technological and organisational complexity etc. one must be very careful in assuming what can be generalised from three case studies. The case studies of this research have focused on issues of communication, coordination, cooperation/collaboration, planning etc. that are general themes reflected in all construction projects. In a global perspective it may be difficult to generalise the findings from the three case studies. However, they served to highlight a number of themes and issues that appear to be of general relevance to further theoretical and practical work with applying a lean perspective to efforts of design/construction integration.

- **Reliability**: A case study is reliable if it can be substantiated that the case study, if re-conducted by a different researcher using the same methods, would result in the same findings and conclusions. For achieving this, the case study strategy and design was critically examined by a second party (the supervisor) who was continuously involved in the ongoing discussion on the subject. This also served as an additional measure that was taken to ensure that the steps taken by the researcher also made sense to an outside party that was not involved in conducting the study. For communicating the case studies, detailed descriptions of case study design, procedures, development etc. have been reported in such detail that similar case studies can be replicated from the descriptions in this thesis.

### 2.4.4. Non-participant observation

For every case study non-participant observation of design meetings was applied, as far as possible, and it constituted the main pillar of the data collection. It was given high priority as many issues or processes affecting design/construction integration are likely not to be (explicitly) recorded in any other project documentation. For the present research an additional strength of direct observation was that this method was suitable to further contributing to understanding of the contextual circumstances in which the design/construction integration theme is embedded. A potential weakness

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20 Draft case reports were not distributed to project participants since an experience from the case studies was that feedback on written material (e.g. questionnaires) was very difficult to obtain. Since the many observations from the case studies could be checked against meeting minutes etc. it was prioritised that the limited time the researcher could hope for the project participants to devote the research would be better spent on providing the researcher with more information.
2. Research strategy and method

Of direct observation is the risk of the very consciousness of reflexivity – the event may progress differently because it is being observed (Yin 1994). While it is impossible to eliminate this risk completely it is the impression of the researcher that his presence did not directly affect the events monitored. Design and project meetings of the Danish case studies took place in a context where it is not unusual for project participants to see students participate in meetings as part of traineeships etc. The researcher observed a large number of meetings and participants seemed not to pay special notice to this. A few times during informal conversations with individual meeting participants prior to meetings or during lunches (that were often served all meeting participants, including the researcher, when meetings ended) the researcher a few times brought up such questions, e.g. if, according to the impression and experience of meeting participants, student observation affected construction professionals and if the presence of students had any influence on the course of the meetings? There appeared to be a strong consensus that participants in construction meetings were fully used to meet student observers and that their presence made no practical difference. One participant expressed that it would perhaps make a difference to some participants if meetings were being recorded electronically or if events were monitored by someone holding a distinctive professional authority as e.g. a university professor.

The researcher aimed to obtain access to as many design/construction related project meetings as possible, in particular specific design meetings. The number of meetings attended varied considerably between the different projects studied. With one exception (two process evaluation meetings at case project III, see Chapter 6) audio/video recording was not used for the collection of data from project meetings. From previous experience the researcher knew that construction professionals (at least in Denmark) tend to be uneasy about recording meetings or interviews if controversial issues are discussed. Even if permission to record could have been obtained it was considered likely that this would affect some meeting participants to an extent where it would influence the course of the events. It was therefore decided to rely on notes taken by hand by the researcher during and after each meeting. Subsequently these notes were compared to the meeting minutes in order to check for possible discrepancies. An obvious weakness of this method, is of course, that meeting minutes did not record everything, least of all the social processes of the meetings and thus could not provide a reference for many of the observations recorded by the researcher. Without audio/video recordings this weakness could have been partly compensated by having more than one researcher

21 For all three case projects studied there were plenty of shorter conversations between the researcher and project participants outside the actual meetings monitored. Project participants often asked about the research studies being undertaken; if their own ‘old teachers and professors’ were still active; if the researcher were acquainted with friends or even family members working or studying at the same university department, etc. Many of the conversations provided the researcher with a good possibility to have technical details and participant positions explained or further elaborated, often on the initiative of the interlocutor him-/herself. The researcher was careful not to take a position or in other way ‘become part of the project studied’ but it is of course impossible to say if these conversations had unwanted side effects or not. It should be noticed that avoiding conversation could well have implied a much bigger risk of affecting the project if the researcher thus behaved different from the ordinary student ‘hang-around’ informally observing things, a sight familiar to project participants.

22 The same problem was encountered by Gorse & Emmitt (2003) who also concluded that audio/video recording would not be appropriate for their collection of data from construction progress meetings.
observing the meetings and taking notes, but this was not practically possible for this research project.

<table>
<thead>
<tr>
<th>Case I</th>
<th>Case II</th>
<th>Case III</th>
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<tbody>
<tr>
<td>Project kick-off workshops attended</td>
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<td></td>
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<tr>
<td>Design meetings attended</td>
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<tr>
<td>Other project meetings attended</td>
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<tr>
<td>“Target cost” design meetings attended</td>
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<td></td>
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<tr>
<td>“Lean coordinators’ meetings” attended</td>
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</tbody>
</table>

Table 2.1: Overview of project meetings attended at the three case projects. – Some meetings from Case III are counted as both ‘target cost meetings’ and ‘design meetings’.

2.4.5. Project material/documents
Access to different project material varied from case to case. During the case studies the aim was to gain access to as much project material as possible. Tendering documents, meeting minutes, memoranda and correspondence related to the project design and production-planning phases were the main document sources. The information of this material was primarily used by the researcher to obtain an overview of the individual case projects and to follow their development. This was important as projects were (partly simultaneously) studied in both Denmark and California. The non-participant observation was supported by meeting minutes and official project documentation which contributed substantially to the researcher’s interpretation of the information recorded during meetings.

2.4.6. Interviews
The original intention was to finalise the data collection of each case project by a number of interviews with key participants. The purpose of such interviews was to examine in more detail some of the findings made during the observation period. Interviews were planned to be ‘semi-structured qualitative’ in their approach. The semi-structured qualitative interview is suitable for revealing personal perceptions and experiences that are difficult or impossible to measure or quantify through other methods.
Persons to be interviewed were to be selected on the basis of the findings from the observation period. Interviews were to follow a structure where questions had an open-ended nature in respect to aspects where the individual informant’s elaborative explanations were of special interest. – Due to unforeseen circumstances these concluding interviews with individual project participants could not be conducted as part of this research, but a group interview was conducted with key participants of Case III (see below).
For the outline for the group interview, see Appendix 4.

2.4.6.1. Audio/video recording
The original plan was to execute the interviews without the use of voice recorders. As discussed above, it was the experience of the researcher that construction professionals were uncomfortable by electronic recordings and often reluctant to accept being recorded. However, for the case study in California (Case 3) voice recording was used during two events that were partly semi-structured group interviews and partly a process-mapping exercise where project participants evaluated the target value design process and mapped the procedure they had ended up
following (see Chapter 6). Meeting participants had agreed to the evaluation meetings being audio recorded. The companies they represented had long lasting relationships with each other and several participants were experienced with participating in meetings organised as videoconferences. The assessment of the researcher and local research colleagues was that voice recording would be unproblematic.

2.4.6.2. Revision of interview strategy
Due to a number of unforeseen circumstances regarding the development of the projects studied the interview strategy had to be revised. The first case project (Case I, see Chapter 4) was interrupted by a long postponement which eventually put an end to the case study before interviews had been executed.
The second case study from Denmark (Case II, see Chapter 5) was completed in the second half of 2005 and the original intention was to conduct interviews with individual participants immediately after. However, the researcher’s time became reprioritised by the university department why finalising the case study according to plan had to be given up in order to release resources for other activities.
For the case study from California (Case III, see Chapter 6), individual interviews with a sufficient number of key participants were given up when the client organisation (with short notice) decided that project participants should prioritise two hour-long process mapping/evaluation exercises where the researcher and two local researchers participated and carried out a partial group interview during the events.

2.4.7. Application of questionnaires (Case II & III)
The strategy of not using questionnaires was slightly revised following an agreement with a contractor in Denmark whose project portfolio was of critical importance to the research. Access to this contractor’s projects was essential since no other local company was about to run projects applying lean approaches to design phases.
Prior to the data collection from the second case study (rehab-housing in Denmark) the contractor had just had its first ‘lean design project’ evaluated by an external consultant and the company was very interested in the research complementing this evaluation in such a way that the two studies would enable comparison between the individual construction projects. The researcher therefore agreed to apply a questionnaire survey for the second case study (Case II, see Chapter 5).
It was later realised that the contractor’s wish was difficult to fulfil completely since the previously completed evaluation appeared to be largely incompatible with the present research in terms of objectives and method. The previous evaluation mostly focused on participant satisfaction regarding the course of the project, the contractor’s lean design concept and the cooperation with fellow project participants. Data had been gathered through questionnaires (with a total response of six questionnaires returned) that were analysed quantitatively, and through one group interview with project participants.

The contractor’s wish was to have the study of Case II executed with application of the same questionnaire that had previously been used in the external evaluation. The researcher was under the impression that the previous evaluation was of some political importance in the contractor’s organisation and knew from experience that the position of the contractor’s main organisation could be vital for project participants’ motivation for sharing information with the researcher. From these considerations it was decided to seek a compromise by developing a questionnaire that would satisfy the contractor while being of some use to the research. Other data
collection activities would continue as originally planned. The external evaluator, who had applied the original questionnaire, was contacted for information about the design of this questionnaire and the strategy of the evaluation. It appeared that the questionnaire had come into existence as a modified version of a questionnaire previously used in evaluation of a partnering initiative in the construction sector. This evaluation had been executed by a third person no longer employed in the organisation responsible for the evaluation which is why tracing its origin any further was not pursued.

### 2.4.7.1. Design of questionnaire

The strategy was to critically analyse the previously used questionnaire to find questions relevant to the research and use that as basis for developing a new questionnaire. The first half of the previously used evaluation questionnaire focused on the respondents’ perception of communication, coordination, cooperation and dispute resolution within the project evaluated, all questions that were relevant to the present research’s focus on design/construction integration. The second half of this questionnaire focused on participants’ satisfaction with using the Last Planner System for task management in the design phase. Therefore the first part of this questionnaire was adopted (with minor rephrasing of the questions) and the second part of the questionnaire was substituted with a series of questions focusing on the integration theme through indirect questions. The idea was to at two stages during the project (at the beginning and at the end of the main phase of the detailed design process) gather information on individual project participants’ expectations regarding later project stages and concerning technical and organisational challenges that they identified in the project. Combined with observations from e.g. meetings this could provide valuable information about the degree to which certain issues, identified by designers as being critical for successful design/construction integration, were in fact being brought up and dealt with in the project. Through a third round of questionnaires at the end of the project, and subsequent interviews with respondents, it would be possible to follow the development of expectations and experiences throughout the whole period studied, and thus get a more detailed picture of the course of development of the project than what could have been achieved through simple retrospective project evaluations (as are commonly applied). The questionnaires were not expected to provide the main data for analysis but to support the main collection activities of observations and interviews. It was hoped that questionnaire feedback could help identify issues for which extra attention should be paid during observations and interviews.

(For the questionnaires used, see Appendices 1-3)

<table>
<thead>
<tr>
<th>Data collection method:</th>
<th>Case I</th>
<th>Case II</th>
<th>Case III</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-participant observation</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Questionnaires</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Individual interviews with project manager</td>
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<td>●</td>
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<tr>
<td>Individual interviews with other project participants</td>
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<tr>
<td>Conversations with project participants</td>
<td>●</td>
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<tr>
<td>Group interview</td>
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<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Archival studies of project documents</td>
<td>●</td>
<td>●</td>
<td>●</td>
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</tbody>
</table>

Table 2.2: Data collection methods applied for the individual case studies.

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23 When presented with this questionnaire design the contractor was satisfied and did not intervene in the data collection.
2.4.8. Comments on methodology for the individual case studies

2.4.8.1. Case I
The study of this case was conducted through non-participant observations of design committee meetings, interview with the design manager, and conversations with key personnel of the project. At the time of the study there were no possibilities of doing further observations on other organisational levels. In the autumn of 2003 the project, still in its early stages, was postponed without a set date of continuation. A long period of no activity and new postponements had passed before it was realised that this case study would not, as originally expected, provide a basis for studying integration of design and construction throughout all the phases from conceptual design to project completion. In February 2004 it was clear that the postponement would eventually be so long that it would prevent further studying of the case within a reasonable timeframe.24 Because the researcher long expected to be studying the project in its later stages, no action was taken to carry out interviews at the time of the first project postponements. Recognising that there is a limit to the amount of time a researcher can have access to interviews with the same person, it was expected that the benefits of interviewing at this stage would be inferior to those of awaiting more promising situations. Had the researcher anticipated the full duration of the project postponements, interviews with project participants would have been undertaken in the autumn of 2003.

2.4.8.2. Case II:
The study of this case was conducted through non-participant observations of design committee meetings and other project meetings, conversations with key personnel of the project, and through review of project material. Two rounds of questionnaires were used for obtaining additional information about how key project participants perceived the project and its challenges, issues of collaboration, the lean design/construction initiatives applied etc. For questionnaire designs, see Appendices 1 and 2. As mentioned above, the plan of studying the main production phases of this case project had to give way for other assignments (a situation which could not have been foreseen when the research strategy was made) why finalising the case study with a third round of questionnaires and final interviews with individual project participants had to be given up.25

2.4.8.3. Case III:
The study of this case was conducted through non-participant observations of design committee meetings and other project meetings, conversations with key personnel of the project, and through review of project material. In the design phase one round of questionnaires was used with the same purpose as the questionnaire application in Case II, but with special emphasis on the processes of designing to target cost.

24 An additional consequence of the project postponement was that it would not be possible for the researcher to study one of the four subsequent projects planned.
25 It is the hope that some later possibility will allow a follow up study on case project II.
Two project evaluation meetings were monitored and a semi-structured group interview conducted in connection to these events. In continuation of the researcher’s own data collection, further studies of the case project have been taken up by Glenn Ballard (University of California at Berkeley). At present these studies are still ongoing but Mr. Ballard has kindly shared his notes and preliminary findings that have been useful as an additional check list for comparison with the researcher’s own observations.

2.4.9. Reflections over ethical issues

Ethical issues have been considered in regard to the case study design, the selection of data collection methods throughout all phases of conducting and documenting the case study. Critical reflections on ethical aspects of the case studies have been an ongoing process. Inspiration and guidance regarding ethical questions have been found from the Danish Social Science Research Council’s guidelines on research ethics in the social sciences.26

A particular concern was to secure that the individual persons and organisations involved in the three case projects would not in any way experience unwanted impact or discomfort resulting from the research, and that they would all be aware of the ways in which their actions were being studied and with what purpose this took place. A difficult question to the researcher has been to draw the line between what should be considered case data and what should be treated as information that the researcher had been entrusted in private. Informal conversations with project participants (e.g. over the lunch break, by the coffee machine or during breaks in meetings), usually on the initiative of the project participants themselves, have been an important source of information for the researcher to whom additional explanation from e.g. designers was necessary to achieve sufficient understanding of the often very technical issues dealt with during the activities observed. Information obtained through informal conversations etc. was also crucial for obtaining an overview of what went on in relation to important case project activities that for different reasons could not be monitored by the researcher in person. Participants were guaranteed that all information would be handled with confidence and individual persons and organisations were granted anonymity in the published research.27

Though having been informed about and accepted that the researcher was present for studying the case projects in their organisational contexts, it was not always clear if the project participants remembered this when talking informally, and in some cases the researcher had to explicitly ask individuals about the degree of confidentiality regarding certain information. The general impression of the researcher was that project participants in general spoke to him with great straightforwardness and trusted

26 For an elaboration of these guidelines see e.g. (Andersen 1999, pp. 315-323) or the Internet pages of the Danish Research Agency: http://forsk.dk (last visited April 21st 2006).
27 One disadvantage of this is approach is of course that it will be difficult for others to critically examine the findings of the case studies by going back to the original sources of information for comparison with what has been reported in this research. Unfortunately a high degree of anonymity and confidentiality was an unavoidable price to pay for access to case data.
that he could and would judge in what level of detail the information could be reported in the research.\textsuperscript{28}

\textbf{2.4.10. Concluding remarks}
It is the belief of the researcher that the thesis provides a description of the case findings that is sufficiently detailed for the reader to get an appropriate understanding of the case projects and the themes that they highlighted while maintaining the anonymity of those involved. A higher degree of detail and information regarding the case project phases and the activities observed would not have contributed decisively to communicating the results of the research. Combined the data collection methods help to illustrate complex issues relating to the application of lean approaches to construction and to the integration of design and construction.

\textsuperscript{28} Some participants made this expectation explicit. In some cases the researcher was given access to confidential meetings among a selection of stakeholders to whom it was critical that the researcher did not share sensitive information processed with other project participants/stakeholders.
Chapter 3

Towards an understanding of ‘lean’ – literature review and discussion
3. Towards an understanding of ‘lean’
– literature review and discussion

This chapter sets out to discuss the concepts of ‘lean construction’ and ‘lean design’ through an introduction to previous work on the topic. The origins of ‘lean production’ and its source of inspiration from a Japanese production management philosophy will be introduced and ‘lean production’ will be reviewed and discussed in the light of different co-existing definitions. Critical arguments - questioning some of the assumptions on which trendsetting literature promoting ‘lean’ is based – will be discussed.

The area of ‘lean construction’ will be introduced and different (co-existing or competing) definitions presented and considered. Academic criticism directed at ‘lean production’ and ‘lean construction’ will be discussed and the chapter will examine how ‘lean construction’ and ‘lean design’ can be understood in relation to the present research. The chapter will conclude by proposing a working definition of ‘lean’ in building design and construction.

3.1. Introduction to ‘lean’ - a philosophy of enhancing value and reducing waste

The ‘lean’ approach applied in construction was originally adopted from manufacturing, as can be seen from e.g. Alarcón (1997) and some of the five contributions from the 1st International Workshop on Lean Construction (Koskela 1993; Tanskanen et al. 1993; Ballard 1993). As will be discussed later, there is no global explicit definition of what is meant by “lean construction”. This is not surprising when considering the absence of consensus regarding a common definition of ‘lean production’, the forerunner of ‘lean construction’.

Organisation concepts, such as ‘lean production’ among others, can be loosely defined as: “A more or less coherent prescriptive vision of organisational design (…). They can be seen as codified bodies of knowledge on how to organise, and as such they figure prominently in business curricula as prescriptive ideals to be followed” (Benders 1999). Characteristics of organisational concepts are that they a) leave room for interpretation and b) promise performance improvements. Organisation concepts that become ‘management fashions’ share these to a high degree and tend to become de-coupled from their original meanings as they are diffused, interpreted, translated, adopted and adapted (Abrahamson 1996; Kieser 1997). Research has suggested that this phenomenon has had significant impact on the diffusion of ‘lean production’,

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29 Early years of the ‘lean’ debate focused highly on individual practices, especially just-in-time (JIT) and before the term ‘lean’ had become generally adopted, the approach was often described as a philosophy (e.g. in the first major literature review on the theme, conducted by Golhar & Stamm (1991), and in the first research on the applicability to construction conducted by Koskela (1992)). Where the earliest western publications focused more narrowly on manufacturing processes, Liker (1996; 2004) explicitly suggests the notion of lean as a ‘philosophy’ for how to conceive business, production and processes underpinning approaches, method and tools of lean production/manufacturing. From this perspective Bhasin & Burcher (2006) offers a comprehensive literature review on ‘lean’ and argues that successful practical implementation requires that lean is viewed as a philosophy rather than as an actual strategy.

30 Two annual events were held under the titles 1st and 2nd International Workshop on Lean Construction before the event from 1995 was named “The Annual Conference of The International Group for Lean Construction”.

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Bo Jørgensen (2006) 51
resulting not only in the term being de-coupled from its original meaning into covering many different initiatives but also in widespread ‘rhetorical adoption’ often dominating over ‘substantial adoption’ (Benders 1999; Benders & van Bijsterveld 2000).

In spite of this variety of meanings ascribed the label ‘lean’ there appears to be a few largely common elements of these definitions/conceptions/interpretations:

- A focus on eliminating/reducing waste and sources of waste in relation to the delivery of artefacts or services that represent value to the end customer;
- End customer preference is adopted as the reference for determining what is to be considered value and what is waste;
- Management of production and supply chain from a (customer) demand pull approach;
- Approaching production management through focus on processes and flows of processes;
- An (at least to some degree) application of a system’s perspective for approaching issues of waste elimination/reduction.

The concept of ‘customer’ is very central in the lean philosophy. A main principle is to consider all downstream operations as ‘customers’ while value is defined only as perceived by the final customer (the end customer). This involves some important implications when applying the lean philosophy to construction (discussed below and in Chapter 7).

Different definitions and the meanings ascribed ‘lean production’ will be discussed following an introduction to the development of lean production.

3.2. History and development of the management concept ‘lean’

Before commencing a discussion devoted to ‘lean construction’ it is expedient to closer examine the origin, history and development of the parent concept ‘lean production’ and the content to which the term refers.

3.2.1. The term ‘lean production’ and its origin

The introduction of the term ‘lean production’ or ‘lean manufacturing’ has been credited to John F. Krafcik (1988) by several authors (e.g. Cusumano & Nobeoka 1998; Womack et al. 1990; Benders & van Bijsterveld 2000). Krafcik, who as a student had been involved in the MIT International Motor Vehicle Program, argued that productivity and quality of the auto industry’s assembly plants did not depend on the geographical location of the individual plant but on its production policy.

Explaining the philosophy and principal approach of the Toyota Production System and how it differed from traditional ‘Fordist’ large-batch mass production, Krafcik (1988) introduced two terms: ‘buffered’ and ‘lean’ production systems:

“The reasons for selecting these terms are obvious. The production systems of most Western producers throughout most of the postwar period were buffered against virtually everything. Inventory levels were high, buffering against unexpected qualify problems; assembly lines had built-in buffers to keep production moving if equipment broke down;
legions of utility workers were kept on the payroll to buffer unexpected periods of high absenteeism; repair areas were huge to buffer against poor assembly line quality, and so on.

Other plants, best exemplified by Toyota, truly were lean operations. Inventory levels were kept at an absolute minimum so that costs could be shaved and quality problems quickly detected and solved; bufferless assembly lines assured continuous-flow production; utility workers were conspicuous only in their absence from payroll. If a worker was absent without notice, the team would fill in; repair areas were tiny as a result of the belief that quality should be achieved within the process, not within a rectification area.” (p. 44-45)

Krafcik explicitly defines ‘lean production’ with reference to applied procedures as just-in-time (JIT), single-piece flow, and multi-skilled employees organised in teams. For Krafcik’s categorisation of production systems, see Figure 3.1.

Figure 3.1: A categorisation of production systems (TPS = Toyota Production System). The Figure illustrates Krafcik’s distinction between ‘lean’ and ‘buffered’ production systems in relation to dominating car manufacturing approaches of the 1980s. The figure also indicates their development from the original ‘Fordist’ model of mass production. - From (Krafcik 1988)
Krafcik does not present ‘lean production’ as being fundamentally different from traditional Western mass production but regards it a Japanese interpretation and adaptation of this:

“… many of Ford’s principles in their purest forms are still valid and form the very basis of what we now know as the Toyota Production System (TPS). Many Western [automobile assembly] plants have relearned these basic concepts as interpreted by some of the Japanese auto makers (…)” (p. 42)

“The Japanese translation of the Fordist system in this area was simple. Toyota was the great innovator here, taking the minds + hands philosophy of the craftsmen era, merging it with the work standardization and assembly line of the Fordist system, and adding the glue of teamwork for good measure. (…) Scientific management techniques were not thrown away; they were just performed by different, more appropriate, employees. (…) Finally management organized workers into teams (…) more capable of reacting to shifts in production content than were the rigidly standardized Fordist laborers and supervisors.” (p. 43)

Krafcik’s understanding of ‘lean production’ appears to be consistent with the Toyota Production System (which he defines as “original Fordism with a Japanese flavour”) as it has been described or discussed by previous or contemporary authors31 (e.g. Sugimori et al. 1977; Shingo 1981; Monden 1983; Dohse et al. 1985; Ohno 1988). Most ‘pre-Krafcik’ publications on Japanese car manufacturing appear to be Japanese published titles.

The term ‘lean’ was widely popularised by Womack, Jones & Roos (1990) through ‘The Machine that Changed the World’ in which they described the production philosophy and system of Toyota, and referred to this as the definition of ‘lean production’. The authors claimed that this production philosophy and Toyota’s production management principles were superior to all others, while also being globally applicable to all kinds of production. A claim also made by Monden (1994) in his description of the Toyota Production System. Womack et al. (1990), however, go as far as to suggest that ‘lean production’ is destined for becoming the sole production system of the world.32

The purpose of the present chapter is not to discuss phenomena of management fashions. However, for providing an overview of the diffusion of ‘lean’ and the

31 It should be noted that, with the exception of Monden and Dohse et al., all of these authors were personally involved with Toyota Motor Cooperation. Sugimori, Kusunoki, Cho, Uchikawa, Shingo and Ohno were employed by Toyota in Japan while Krafcik himself had worked on the GM/Toyota joint venture plant NUMMI in California.

32 Womack, Jones and Roos conclude their book with the following, and often criticised, statement: “Yet in the end, we believe, lean production will supplant both mass production and the remaining outposts of craft production in all areas of industrial endeavour to become the standard global production system of the twenty-first century. That world will be a very different, and a much better, place.” (p. 278)
diversity of meanings ascribed ‘lean production’ and ‘lean construction’, it is relevant to briefly introduce lean production from the perspective of management fashion.

3.2.1.1. Lean production as a management fashion

For several years during the 1980s Japanese car manufacturing had been a subject of intense attention from the Western motor vehicle industry which kept losing market share to their Japanese competitors (Dohse et al. 1985). It appears that the book by Womack et al. (1990) expanded this interest far beyond the borders of motor car manufacturing and brought it into the general production management debate. The authors had made a large number of unsubstantiated claims that have been heavily debated – and often disproved - by research (discussed later) but they were successful in establishing ‘lean production’ as a recognised production model, despite having defined this very vaguely and thus left wide room for interpretation. This vagueness and openness for interpretation enabled ‘lean production’ to become a management fashion through its interpretability and flexibility through which it could be perceived to address a wide body of industries, enterprises and supply chains irrespective of context (Kieser 1997; Benders & van Bijsterveld 2000). According to Abrahamson (1996) and Kieser (1997) these observations describe prerequisites characteristic for the creation and setting of management fashions. Abrahamson argues that these are not only instrumental for management fashions to diffuse but also serve to shape (fashionable) management techniques that managers look for in their efforts to cope with extremely important and complex managerial problems and challenges. This discussion is taken further by Kieser (1997) who identifies a list of criteria for the setting of management fashions and he identifies lean production as a leading management fashion of the 1990s, and he explains how the style and attributes paved the way for ‘The Machine that Changed the World’ (Womack et al. 1990) to become a trend-setting publication. From this follows that applied ‘lean production’ may appear in many different forms dependent on its adopters/adaptors even though they are all following the same management fashion. Confusion deriving from the lack of clarification regarding the actual meaning of ‘lean production’ is further increased by the findings of research concluding that ‘lean production’ (described by Womack et al. as a largely uniform production system) in fact represents a generalisation of Japanese production systems (e.g. Bartezzaghi (1999)). Highlighting this confusion Boyer & Freyssenet (2002) argues that ‘lean production’ appears to be a combination of the Toyota Production System (reduction of costs at a constant production volume) and the Honda System (having greater emphasis on technical innovation and product development).

Kieser (1997) makes an important observation in his critical discussion of lean production as a management fashion, where he draws attention to the lean model promoted by Womack et al. (1990) representing a radical shift away from a more than one decade long focus on technology and technological development as the issue most central to the further improvement of industrial productivity. Womack et al., in turn, promoted an approach in which high-tech production machinery was explicitly emphasised as being of modest importance. Instead they accentuated the importance of management as the single key issue for driving down production costs. This, Kieser argues, matched perfectly the emerging trend of the 1990s that became ‘the decade of management’.
In research *The Machine That Changed the World* (Womack et al. 1990) has been comprehensively criticised for its omission to define lean production and for the very vague and interpretable representation of the production system promoted.\(^3\) The book has nevertheless become extremely influential and is commonly cited as if it was an academic research contribution representing the results of the MIT International Motor Vehicle Program (IMVP), a major 5-year global study of the car manufacturing industry, led by the three authors. In the introduction to the book the authors explicitly state that they intended “not to write an “academic report on our work” (p.8). On the same page they emphasise that the book “presents the personal views of the three Program leaders” and that it “should not be taken for an official statement agreed to by all [IMVP research] participants” (p. 8). It appears that not all participants agreed on every point discussed, but the book does not give any indications of the issues that were subjects to disagreement. Considering that a large number of researchers were involved it is not surprising that the book does not represent a full consensus regarding the views presented. But it is remarkable how influential a non-academic publication of three program leaders’ personal opinion has proved itself with regard to the production (and construction) management debate and research of the 1990s and early 2000s.

To conclude, it must be acknowledged that (Womack et al. 1990) - whatever this popular management book does or does not represent - is a very important publication in debate and research on ‘lean’ and it is therefore frequently cited as an important reference for this chapter.

3.2.2. Origin and development of the Japanese model ‘lean production’

The approach that later became famous under the label ‘lean’ developed in postwar Japan as a result of efforts to adopt (production) management practices from the US to reconstruct Japan’s industry in the years after World War II (Ohno 1988; Womack et al. 1990; Berggren 1990; 1993b; Morris & Wilkinson 1995; Boyer & Freyssenet 2002). Especially the work undertaken by Toyota appears to have been pivotal for developing practices later imitated by the West.\(^3\) Japanese adopters became *adapters* partly due to interpretation of the original management principles, but mostly due to local contextual circumstances requiring different emphasis on individual elements of the concepts adopted. For example, the Japanese motor vehicle industry suffered from significant setbacks within production facilities, financial resources were modest, producers experienced severe scarcity of materials and machinery, and the market requested a large variety of different product models (e.g. cars and trucks) in low volume. Under these conditions it was feasible, if not necessary, to increase flexibility and to manage production with a focus on eliminating waste instead of applying the pure American ‘Fordist’ manufacturing strategy of high-volume mass production with large inventories to buffer the production process from variations and uncertainty (Ohno 1988; Berggren 1990; Womack et al. 1990; Boyer & Freyssenet 2002). The fact that Japan is poor on natural resources and its consequences to Japanese industrial

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\(^3\) Some examples of well-argued but very harsh critique are provided by Berggren (1993a; 1993b); Jürgens (1995); Williams *et al.* (1995); Kieser (1997); Lewis (2000); Boyer & Freyssenet (2001; 2002).

\(^3\) The early work of developing the Toyota Production System, or lean production, was led by Taiichi Ohno and first applied to car engine manufacturing in the 1950s and to vehicle assembly it was applied in the 1960s, but it was not until the wider external supply chain was addressed in the 1970s (where the first supplier manuals were produced) that the approach and principles were shared with companies outside Toyota (Hines *et al.* 2004).
strategies has been emphasised in several publications discussing the origins of ‘lean production’/Toyota Production System (e.g. Sugimori et al. 1977; Ohno 1988; Berggren 1990; Boyer & Freyssenet 2002).

A number of other contextual factors have been identified as being of substantial importance to the development of production systems and management practices of the Japanese auto industry:

- **Nationally determined conditions for profitability** (Jürgens 1995; Williams et al. 1995; Boyer & Freyssenet 2001; 2002);
- **Product characteristics of motor vehicles in low/high volume production** (Ohno 1988; Womack et al. 1990; Cusumano (1994); Katayama & Bennett (1996); James-Moore & Gibbons (1997); Boyer & Freyssenet 2001; 2002; Berggren 1993a; 1993b; Cooney 2002);

Not only did the ‘lean’ production systems of the Japanese motor vehicle industry partly develop in response to contextual circumstances, a comprehensive number of publications have expounded how many of its celebrated benefits and advantages have also in part depended on the conditions under which the Japanese automobile producers operated in the 1970s and 1980s (Dohse et al. 1985; Cusumano 1994; Jürgens 1995; Williams et al. 1995; Katayama & Bennett 1996). Williams et al. (1995) conclude that structural factors, rather than management practices determined the success experienced by Japanese industry following its reconstruction from the postwar years to the end of the 1980s. Comparing production models and systems of the international automotive industry Boyer & Freyssenet (2001; 2002) argued that while Japanese producers had developed practices that were at the time suitable for the circumstances then present in Japan, motor vehicle producers of other countries operated under conditions that favoured other approaches.\[35\] Katayama & Bennett

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\[35\] Boyer & Freyssenet (2001) provide a summary of research results into the auto industry as conducted by the GERPISA network. The report is titled ‘The World That Changed The Machine’, sarcastically illustrating the authors’ criticism of the claims by Womack et al. (1990) who promoted one model as superior to all others regardless of context. An important point made by Boyer & Freyssenet is that **appropriateness** of production models cannot be considered independent from **profitability** (an issue also raised by Jürgens (1995)). A central argument is that literature on lean production (and Japanese production models in general) has omitted to distinguish between productivity and profitability when
(1996) concluded that while lean production was a competitive and effective method of manufacturing within the boundaries of the protected market under the Japanese ‘bubble’ economy of the 1980’s, it is incapable of accommodating larger variations in volume and in particular demand drops. Even small variation often takes production below break-even point.

Since the 1990s several publications have highlighted how changing conditions in Japan have led local car manufacturers (including some promoted by popular literature as ‘leading lean manufacturers’) to radically modify several of the key elements of the ‘lean production’ model as promoted by Womack et al. (1990). This can be illustrated through a few examples: the first example is the just-in-time (JIT) delivery principles. With JIT (originally an invention of Toyota) diffusing into different industries a significantly negative side effect was a heavy increase in traffic resulting from the pressure for smaller, and thereby more frequent, deliveries of materials to factories. This in turn resulted in dramatically worsened traffic congestion (increasing the vulnerability of JIT-based production) and increased pollution, and has led ‘lean’ producers to modify the ‘leanness’ of their supply and delivery systems, soften JIT procedures and even give up the kanban tool (e.g. Cusumano 1994; Katayama & Bennett 1996). A second example is that ‘lean’ Japanese car manufacturers have experienced difficulties recruiting and keeping production staff (partly due to bad working environment), (see. e.g. Berggren 1993b; Jürgens 1995) which have led to modifications of the core principle of maintaining and educating a largely permanent multi-skilled staff (Cusumano 1994). These challenges to the lean production model have been further accelerated by the dramatic economic recession experienced by Japan in the 1990s. This, among other impacts, led to a reduced and fluctuating customer demand for new cars. This challenged the ‘lean’ production systems that, with their non/low stock and pull-structured manufacturing and supply structures, are highly sensitive to variations in production volume (Cusumano 1994; Katayama & Bennett 1996; James-Moore & Gibbons 1997; Cooney 2002; Hines et al. 2004). Some lean producers were thus forced to give up the principles of life-time employment, and even to lay off permanent staff, supplementing a core staff with temporary employees during demand-peak periods. In the mid-1990s Cusumano (1994) concluded that with changing conditions “Japanese companies are now being comparing relative advantages of different production models. However, in context productivity is but one factor of profitability.”

36 Kanban refers to an order- and supply system, where cards (a so-called kanbans) are submitted as representing orders and returned as attached to supplies, procedures that with simple means facilitate a ‘pull approach’ to material logistics. – For further information on kanban systems, see e.g. (Ohno 1988); (Shingo 1989), or (Monden 1994).

37 According to Cusumano (1994) local traffic in some industrial areas in the 1990’s worsened to a point where a government campaign encouraged companies to reduce the frequency of their parts deliveries. It should be mentioned that Monden (1994) argues the opposite, that JIT delivery will ease traffic congestion (p. 349). The argument is brought as a response to non-specified criticism in Japanese and American press and is justified through an example that does however build on the assumptions that trucks will be fully loaded and the flow of deliveries smoothed.

38 Literature (in particular popular management literature) on lean production often emphasise the importance of permanent employment of the production staff (e.g. Ohno 1988; Womack et al. 1990). However, according to e.g. Dohse et al. (1985) famous Japanese practices of permanent employment has always been supplemented by simultaneous employment of temporary staff. It is pointed out that with the high level of systems’ supplies under e.g. the TPS much temporary staff may be employed by the suppliers, and it will be a mistake to conclude that the overall production system (when including the supply chain) operates with a largely permanent staff as emphasised by e.g. (Womack et al. 1990).
forced to become more like everybody else in the world: more profit oriented in the short term!” (p. 32), and Stewart (1998) found that ‘lean production’ was no longer any more Japanese than ‘Fordism’ was American.

From these, and other examples (see Table 3.1), one can conclude that the Japanese ‘lean’ production systems, claimed by Womack et al. to constitute the model for ‘lean production’, is not uniform or static in terms of application, but is dynamic and changes in response to the dynamic environment in which it functions. Studies on transfer of lean production and other Japanese management philosophies, approaches, systems, and tools to the West have shown that Western adoption exhibit high degrees of adaptation, interpretation, partial or sporadic adoption (e.g. adoption of individual elements only) etc. (Jürgens 1995; Lillrank 1995; Morris & Wilkinson 1995; Wilkinson et al. 1995; Benders 1999; Benders & van Bijsterveld 2000; Hines et al. 2004), and that also Japanese transplants in the West have been modified considerably from the official production models of their parent companies, although to very different degrees (Kenney & Florida 1995; Wilkinson et al. 1995). For studies of the transfer of Japanese production and/or management models to alien institutional environments, awareness of industry-specific differences, and even more process-specific differences, is essential (Florida & Kenney 1991; Morris & Wilkinson 1995).

Addressing the lack of clarification regarding the exact meaning of ‘lean’ Hines et al. (2004) argue that the content of the management concept has undergone a significant and still on-going development since the 1980s. Distinguishing between lean thinking at strategic level and lean production at the operational level, Hines et al. identify four phases in the evolution of lean thinking:

- in the 1980s awareness of practices diffused;
- during the first half of the 1990s the focus was on quality;
- the latter half of the 1990s provided a focus on both quality, cost and delivery, while;
- since 2000 lean thinking has offered a strong orientation towards customer value.

While this dynamic character is not surprising, it is paradoxical that professional and academic discourse and debate on ‘the Japanese model’ has largely been dominated by vague or highly implicit definitions promoted by two heavily criticised publications that in fact reject this Japanese model’s dependence on and submission to context.

In the publications (Womack et al. 1990) and, with less self-assurance in their formulations, (Womack & Jones 1996; 2003) the authors state that the ‘lean production’ model will conquer the rest of the world just as they claim it has already conquered the industries of Japan (contradicting the findings of e.g. Berggren 1993a; 1993b; Cusumano 1994; Lillrank 1995; Kenney & Florida 1995; Boyer & Freyssenet 2001; 2002; Cooney 2002). 39 The critical debate on ‘lean production’ and of

39 As observed by Boyer & Freyssenet (2002), it is remarkable that the production system that was claimed to be so superior that the rest of the world will be forced to adopt it to at all survive in the competition, has failed to save its country of origin, Japan, from more than one decade of deep continuous economic recession. The Machine that Changed the World was published almost simultaneously with the burst of the Japanese ‘bubble economy’ which marked the beginning of the long economic recession in Japan.
3. Towards an understanding of ‘lean’

3.2.3. The meaning of ‘lean production’ – different definitions

Despite a relatively high number of publications addressing ‘lean production’ or ‘lean manufacturing’ there are few attempts to explicitly present an exact definition of what is meant by these terms. Many publications refer to ‘lean production’ through explicit references to features of ‘lean production’, while others refer to other publications – most frequently to (Womack et al. 1990) – for clarification regarding its meaning.

As will be illustrated in Table 3.1 below, it appears that a number of different definitions co-exist and that many of these share a number of characteristics emphasising both a waste/value focused thinking/approach applied to a system’s perspective, and principle concepts of customer orientation, pull-logistics and flow-based production management and control (in contrary to push-supplied task-based approaches).

Examples of definitions of ‘lean’ (production) are, in chronological order:

Table 3.1: Examples of definitions/understandings/descriptions of lean production from publications covering almost two decades of 'lean' debate. The definitions of this table draw on a selection of literature on a field that covers thousands of publications. This extract/selection covers both frequently cited as well as less cited academic articles, popular management books, and works addressing lean from a variety of perspectives. Hence this literature selection may not be the most representative possible of the debate that could have been constructed, but its purpose is foremost to illustrate the diversity of often comparatively incoherent definitions upon which the debate is based.

<table>
<thead>
<tr>
<th>Publication</th>
<th>Definition / understanding / description of lean production</th>
<th>Definition explicit</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Krafcik (1988)</td>
<td>“Lean production” as an opposite to “buffered production”. Small batch, non-stock, just-in-time production managed through principles known from scientific management but with an emphasis of combining the (multi)skilling of “taking the minds + hands philosophy of the craftsmen era, merging it with the work standardization and assembly line of the Fordist system, and adding the glue of teamwork for good measure.” (p. 43)</td>
<td>Yes</td>
<td>The author introduced the “buffered/lean” typology as a modification of terms proposed by other researchers from the MIT International Motor Vehicle Program who used the terms “robust” and “fragile” to denote similar concepts. Krafcik highlights some important consequences: “The lean production management policy presents higher risks – any hiccup will stop production totally. But the potential gains are great. Thus, lean operations can be considered high-risk/high-</td>
</tr>
</tbody>
</table>

* Explicit in this table does not refer to exact formulations by the publications but to whether the publications explicitly explain what the author(s) mean, or to what is referred, by ‘lean construction’, or if the interpretation listed in the table’s second column has been deducted from an analysis of the publication.

* Main sources refer to the sources from which the individual publication’s perception of ‘lean’/lean production appears to be adopted.
### Towards an understanding of ‘lean’

<table>
<thead>
<tr>
<th>Author</th>
<th>Definition</th>
<th>Source Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Berggren (1990)</td>
<td>“Lean manufacturing represents factory practices with minimal application of buffers and material on stock, frequent deliveries of components directly to where they will be used (the production line) and with small areas for final adjustment and fitting. (...) Characteristics are harsh selection of staff, widely ramified management structures, strong social pressure for performance, continuous visual control of individual operations and processes, and strict discipline.” (^{42}) (p. 96)</td>
<td>Main sources*: Various.</td>
</tr>
<tr>
<td>Womack, Jones &amp; Roos (1990)</td>
<td>“Lean production is ‘lean’ because it uses less of everything compared with mass production - half the human effort in the factory, half the manufacturing space, half the investments in tools, half the engineering hours to develop a new product in half the time.” (p. 13)</td>
<td>‘Lean production’ is used as referring to approaches, tools and methods through which waste is minimised while end user value is maximised and continuous performance improvement can be achieved. Together these measures are presented as a holistic process-orientated approach addressing design, production, supply, corporate relations, customer relations, and all levels of management and all operations connected (directly or indirectly) to run a business, and to produce and deliver artefacts of value as requested by end customers.</td>
</tr>
</tbody>
</table>

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42 Author’s translation from the original Swedish text.
Employee relations and job security is emphasised as features crucial for adopting the lean production system.

Main sources*: Production system, approaches and philosophies found by Japanese car manufacturers, with emphasis on findings from Toyota. Data provided by the MIT International Motor Vehicle Program.

<table>
<thead>
<tr>
<th>Author(s)</th>
<th>Description</th>
<th>Transferability</th>
<th>Main sources*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Berggren (1993a)</td>
<td>The production management approach described by Womack et al. (1990) and (in addition to a high degree of job security) a rigorous management regime offering anything between bad to reprehensible working conditions (as was described in more detail in Berggren 1990).</td>
<td>No</td>
<td>Various publications from the International Motor Vehicle Program; (Womack et al. 1990); and a variety of studies into working conditions in the auto industry.</td>
</tr>
<tr>
<td>Berggren (1993b)</td>
<td>As (Berggren 1993a).</td>
<td>No</td>
<td>(Womack et al. 1990); (Shingo 1981); various studies into the automobile industry.</td>
</tr>
<tr>
<td>Wilkinson et al. (1995)</td>
<td>“A JIT/TQC [Total Quality Control] is characterized generally by a delegation of responsibility, and accountability, to the level of the team, which means teams take on some of the tasks which traditionally would be undertaken by specialist group, including quality control, the team must have the capability to undertake routine maintenance, housekeeping, machine setting, and detailed production scheduling. Because of its ability to function effectively with relatively small indirect staff, such an organizational form has been characterized as a ‘lean’ production system (Womack et al. 1990).” (p. 820)</td>
<td>Yes</td>
<td>Based on an empirical study the article assesses the transferability of Japanese lean production to an alien institutional environment: Wales. It concludes that the Japanese form of manufacturing organisation is re-created in Wales and its fundamental features, while adapted, are basically not altered.</td>
</tr>
<tr>
<td>Karlsson &amp;</td>
<td>“Lean production is not confined to</td>
<td></td>
<td></td>
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</tbody>
</table>

Bo Jørgensen (2006)
The activities that take place in the manufacturing function of a company, rather it relates to activities ranging from product development, procurement and manufacturing over to distribution.

(...) The ultimate goal of implementing lean production in an operation is to increase productivity, enhance quality, shorten lead times, reduce cost etc. These are factors indicating the performance of a lean production system. The determinants of a lean production system are the actions taken, the principles implemented, and the changes made to the organization to achieve the desired performance.” (p. 25)

Lean production conceptualised as consisting of 4 elements:

- lean development;
- lean procurement;
- lean manufacturing;
- lean distribution; and
- lean enterprise

that builds on fundamental principles of:

- multifunctional teams;
- vertical information systems;
- no buffers;
- no indirect resources;
- networks.

(p. 25-26)

The model “can be used as a checklist for what to aim at when trying to implement lean production. The important point to note, however, is that lean should be seen as a direction, rather than as a state to be reached after a certain time.” (p. 40-41)

Main sources*: (Womack et al. 1990); (Monden 1983); (Shingo 1981).

Identifying weaknesses and disadvantages of lean production, the article concludes that this model needs adaptation to remedy its sensitivity to variability. The authors argue that...
<table>
<thead>
<tr>
<th>Author</th>
<th>Description</th>
<th>Relevant Evidence</th>
<th>Review</th>
</tr>
</thead>
<tbody>
<tr>
<td>Liker (1996)</td>
<td>“Lean production focuses on eliminating waste in processes, including the work-in-progress and finished goods inventories, which are the earmark of mass production. (...) The Toyota Production System is an ongoing evolution of solutions designed to achieve the ‘lean’ ideal. Lean is much more than techniques. It is a way of thinking. It is a whole-systems approach that creates a culture in which everyone is continuously processes and production.” (p. ix) Lean is “A manufacturing philosophy that shortens the time line between the customer order and the shipment by eliminating waste.” (p. 7) Main sources: Toyota Production System, empirical sources; (Monden 1983); (Ohno 1988).</td>
<td>Yes</td>
<td>The book presents principles and methods. It also provides case examples of implementing ‘lean’ in companies in the USA.</td>
</tr>
<tr>
<td>Womack &amp; Jones (1996; 2003)</td>
<td>Lean thinking builds on five principles: Specify value; Identify the value stream; Make value flow; Let the customer pull value; Pursue perfection. Main sources*: Empirical and (Womack et al. 1990).</td>
<td>Yes</td>
<td>The book elaborates some of the principles already introduced in (Womack et al. 1990). Five principles are presented as describing ‘Lean Thinking’ and the approach illustrated through simplified examples of its application in different industries. The authors claim that the approach promoted is applicable and beneficial to any industry and business, and they reject that context is decisive regarding the feasibility of pursuing this strategy.</td>
</tr>
<tr>
<td>Cusumano &amp; Nobeoka (1998)</td>
<td>“Lean refers to a general way of thinking and specific practices that emphasize less of everything – fewer people, less time, lower costs.” (p. 4) Main sources*: Principles described by (Womack &amp; Jones 1996), (Womack et al. 1990) and Empirical studies from the automobile industry.</td>
<td>Yes</td>
<td>The book focuses on principles of multi-project management and product development.</td>
</tr>
<tr>
<td>James-Moore &amp; Gibbons (1997)</td>
<td>“In simple terms lean manufacture was defined by Womack et al. as: • Integrated, single piece production flow, small batches, just-in-time giving low inventory;</td>
<td>Yes</td>
<td>The article questions if methods of lean production are suitable and applicable in industries characterised by highly differentiated,</td>
</tr>
</tbody>
</table>
3. Towards an understanding of ‘lean’

- Defect prevention, not fault rectification;
- Production pull, not push with smoothed demand;
- Flexible team-based work organization with multi-skilled workforce and few indirects;
- Active involvement in root cause problem solving to maximize added value;
- Close integration from raw material to customer through partnership.

We added what we believe to be one further ingredient based on the work of Clark and Fujimoto:
- Greatly reduced overhead burden by the use of matrix teams, simplifying information flow and processing, enabling flatter organization structures.”

Main sources*: (Womack et al. 1990); (Monden 1983).

| Bartezzaghi (1999) | “lean production, understood as all those aspects of the Japanese production system with universal validity, …” (p. 230) “a generalisation of the Japanese production system, …” (p. 232) | Yes | The article argues that lean production lacks proper definition and questions if it constitutes a coherent paradigm (contrary to what has been promoted by lean proponents). |
| Benders (1999) | Practices described by Womack et al. (1990) and/or the micro level’s interpretation and/or (partial) adoption of these. | Yes | Based on an empirical study from the Netherlands the article illustrates how interpretable management fashions, in this case lean production, in practice become construed at the whim of decision makers. It is shown how different practices thus emerge and become locally institutionalised as meaning ‘lean production’. Issues that are further discussed by Benders & van Bijsterveld (2000). |
| Benders & van Bijsterveld (2000) | Lean production is understood on three levels:  - The practice at Toyota Motor in Japan;  - As described in (Womack et al. 1990);  - As received/interpreted and/or institutionalised in local context. | Yes | Based on empirical studies from Germany the article argues that ‘lean production’ has been used as a label for a number of different down-sizing initiatives and that the meaning of ‘lean production’ – through a process of local |
3. Towards an understanding of ‘lean’

<table>
<thead>
<tr>
<th>Author</th>
<th>Main sources*; (Womack et al. 1990); (Womack &amp; Jones 1996); (Monden 1983); (Ohno 1988); empirical studies.</th>
<th>interpretation, adaptation, adoption, and institutionalisation - has become de-coupled from the original meaning of the approaches and methods. The article concludes that rhetorical adoption often surpasses substantial adoption.</th>
</tr>
</thead>
</table>
| Lewis (2000) | Lean production must be understood in two separate dimensions:  
• as an outcome of organisational initiatives, and;  
• as a more ambiguous and uncertain process whereby an operation becomes lean.  
(p. 961)  
Lean production as a process:  
“Improving flow of material and information across business functions; An emphasis on customer pull rather than organisation push (enabled on the shop floor with kanban) and; A commitment to continuous improvement enabled by people development.”  
(p. 963)  
A number of elements characteristic to lean productions are identified as sub-issues of manufacturing processes, human resources, and supplier inputs. | Yes | The article argues that core principles of lean production have become established practices in industry. Regardless of whether lean production may in the late 1990s have become less fashionable, the article discusses lean production in relation to issues of sustainable competitive advantage. It is argued that lean production is very difficult to define and it is concluded that each firm is likely to follow. A more or less unique lean production trajectory. |
| Cooney (2002) | “Lean takes a broad view of the production and distribution of manufacturers, developing a production concept that encompasses the whole manufacturing chain from product design and development, through manufacturing and distribution. (…) lean production rests upon a distinctive approach to product flow – just-in-time flow - …” (p. 1130)  
Main sources*; (Womack et al. 1990); (Ohno 1988); (Womack & Jones 1996); (Benders & van Bijsterveld 2000); (Lewis 2000). | Yes | The article is critical to the claims of e.g. Womack et al. (1990) and Womack & Jones (1996) and concludes that ‘lean’ is not a system with universal applicability. Cooney emphasises that the fact that batch and mass production are adopting some lean practices does not imply that the adopters are ‘in transition’ to lean production. |
| Liker (2004) | Lean production/TPS is:  
• “a consistent way of thinking;  
• a total management philosophy;  
• focus on total customer satisfaction;  |

The book describes 14 management principles from Toyota. The Toyota Production System (TPS) is referred to as the model.
3. Towards an understanding of ‘lean’

- an environment of teamwork and improvement;
- a never-ending search for a better way;
- quality built in process;
- organized disciplined workplace;
- evolutionary.”

(p. 297)

A lean enterprise is “the end result of applying the Toyota Production System to all areas of your business.”

(p. 7)

Main sources*: Empirical studies at Toyota; (Womack et al. 1990); (Womack & Jones 1996); (Ohno 1988).

<table>
<thead>
<tr>
<th>Source</th>
<th>Description</th>
<th>Validity</th>
</tr>
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<tbody>
<tr>
<td>Hines, Holweg &amp; Rich (2004)</td>
<td>“Lean exists at two levels: strategic and operational. The customer-centred strategic thinking applies everywhere, the shop-floor tools do not. (...) We therefore encourage the use of lean production for the shop-floor tools following Toyota’s example, and lean thinking for the strategic value chain dimension.” (p. 1006)</td>
<td>Yes</td>
</tr>
<tr>
<td>Bhasin &amp; Burcher (2006)</td>
<td>As (Liker 1996) with the elaboration that ‘lean’ is to be viewed as consisting of a philosophy, and practices, tools or processes: “a philosophy that when implemented reduces the time from customer order to delivery by eliminating sources of waste in the production flow”. (p. 57)</td>
<td>Yes</td>
</tr>
</tbody>
</table>

The article argues that the terms ‘lean’, ‘lean thinking’, and ‘lean production’ have changed their meaning when ‘lean’ has developed in terms of understanding and applied practice. The key argument is that the value dimension has gained stronger emphasis in the common conception of lean since 2000.

Yes

The article is based on a very comprehensive literature review – though with very little emphasis on research discussing HR implications - and concludes with proposing a hypothesis that should be tested through further research: that “a cocktail of common ingredients are viewed indispensable for a successful [lean] implementation:
1) simultaneously apply five or more of a list of technical tools identified;
2) view lean as a long term journey;
3) install a continuous improvement viewpoint; and 4) make numerous cultural changes embracing empowerment and sponsor the lean principles throughout the value chain.”

Bo Jørgensen (2006)
Table 3.1 illustrates some inconsistency in the perception of lean construction and shows that different competing definitions co-exist. Considering the lack of explicit definition and the characteristic interpretive nature of the lean production model that was promoted to the wider public by Womack et al. (1990) a high degree of such diversity is foreseeable (Abrahamson 1996; Kieser 1997). Kieser (1997), whose conclusions are supported by the differences in definition demonstrated in Table 3.1, has - with the specific reference to lean production - described the mechanisms behind diffusion and continuous reinterpretation of organisation concepts that become management fashions (discussed above).

Table 3.1: Myth versus reality of the Toyota Production System. - From (Liker 2004).

<table>
<thead>
<tr>
<th>Myth: What TPS is not</th>
<th>Reality: What TPS is</th>
</tr>
</thead>
<tbody>
<tr>
<td>A tangible recipe for success</td>
<td>A consistent way of thinking</td>
</tr>
<tr>
<td>A management project or program</td>
<td>A total management philosophy</td>
</tr>
<tr>
<td>A set of tools for implementation</td>
<td>Focus on total customer satisfaction</td>
</tr>
<tr>
<td>A system for production floor only</td>
<td>An environment of teamwork and improvement</td>
</tr>
<tr>
<td>Implementable in a short- or mid-term period</td>
<td>A never-ending search for a better way</td>
</tr>
<tr>
<td></td>
<td>Quality built in process</td>
</tr>
<tr>
<td></td>
<td>Organised disciplined workplace</td>
</tr>
<tr>
<td></td>
<td>Evolutionary</td>
</tr>
</tbody>
</table>

Hines et al. (2004) made an important finding when establishing that the very concept of lean production has undergone significant development over the past two decades. Hines et al. also specified characteristics of four phases in the diffusion and evolution of lean debate (discussed above). However, where Hines et al. seem to generalise their findings, a number of empirical studies have documented the existence of highly diverse diffusion and translation processes in different national or local environments, industrial sectors and even between different plants within the same companies (Jürgens 1995; Kenney & Florida 1995; Morris & Wilkinson 1995; Benders 1999; Benders & van Bijsterveld 2000).

Where the findings of Hines et al. may be true for industrial forerunners and literature trends of lean production, there is not sufficient information to conclude that they are representative for lean production at large. In relation to the present research the most important observation by Hines et al. may well be that the customer-value dimension of lean thinking has gained momentum in recent years’ approaches to the application of lean philosophy. An obvious question is why the value perspective, being a distinct and important element of the philosophy, has been overshadowed in a debate that became largely productivity focused? The purpose of this thesis is not to study

\[\text{\textsuperscript{43}}\] Studying the transfer of management practices from Japanese car manufacturing plants to new transplants in the alien environment of Wales and the UK, Morris & Wilkinson (1995) found that despite considerable adaptation took place, core ideas and principles were not fundamentally changed.

\[\text{\textsuperscript{44}}\] This finding is supported by Schonberger (2005) who presents examples of what he calls ‘lean extended’ which represents the current state-of-the-art lean where issues of customer value and supply chain collaboration has been given more weight than in the traditional Toyota Production System.
this particular topic, but it is worthwhile noticing how this bias reflects the way lean production was originally marketed to industry as ‘the way’ to dramatically cut costs while increasing productivity. Empirical studies have revealed how ‘lean’ has often been used as a label for initiatives that were essentially little more than cost-cutting or down-sizing exercises, which have contributed to the de-coupling between the original meaning and local interpretations (illustrative examples are: Benders 1999; Benders & van Bijsterveld 2000). It must of course also be acknowledged that customer value aspects are far more intangible and difficult to approach, not least when seeking concrete action that can shape initiatives.

Another important observation regarding the diversity in definitions and application of the lean philosophy as ascribed the Toyota Production System, is the importance of experimentation. The system grew out of four decades with systematic experimentation within the company and it builds on knowledge of which much is tacit - something not always grasped by visitors who then mistake practices observed for the system itself (Spear & Bowen 1999). The chief engineer behind the development of the Toyota Production System, Taiichi Ohno, argued (1988) that the partly implicit nature was a central feature of the TPS. The system was supposed to be subject to constant development, which Ohno believed would be impeded once detailed specifications of procedures were written down. Ohno found that once formulated on paper, practices and procedures were less likely to be questioned and improved. This does not necessarily contradict the principles of the consequent use of highly standardized and well-described work tasks also promoted by Ohno. Ohno’s aversion to printing of detailed descriptions of the production system regarded the system itself, and not the individual work descriptions and standardisation of work tasks. Spear & Bowen (1999) and Liker (2004) have described how the production management at Toyota prioritises systematic experiments. These are conducted through meticulous practices that apply a scientific approach to formulating hypotheses that can be tested and thus provide data to support the continuous implementation of incremental improvements throughout the system. With micro level experimentation as a vital element of the approach, divergence in emerging practices should not appear surprising.

3.2.4. Waste and value
Elimination/reduction of waste and a focus on (end) customer value – which was repeatedly emphasised issues in the early trendsetting literature as (Ohno 1988), (Shingo 1988), (Shingo 1989) and (Womack et al. 1990) - appear to be the most common features of the many different interpretations encountered in publications.

3.2.4.1. Waste
Waste is the best specified and most tangible of these two parameters. A discussion of different wastes and their nature has been provided by Ohno (1988) who identified seven different wastes:
1. Overproduction;
2. Correction;
3. Material movement;
4. Processing;

---

45 The systematic approach to continuous improvement is commonly referred to by the popularised term ‘kaizen’.
5. Inventory;
6. Waiting, and;
7. Motion.

Of these wastes the first five refer to the flow of material, and the last two to the work of production staff.

When approaching the theme of waste elimination/reduction waste is commonly divided into two categories:

- **Type I waste (‘muda’)**:
  Processes/activities that create no value as perceived by the end customer but which are indispensable for delivering what actually represents value to the customer. - Thus ‘type I waste’ cannot be eliminated but should be reduced to the widest possible extent.

- **Type II waste (‘muda’)**:
  Processes/activities that create no value as perceived by the end customer but which are no requirement for the delivering of the product. – ‘Type II waste’ should therefore be eliminated immediately.

### 3.2.4.2. Value

While many publications refer to (end) customer value, very few specify how value in this respect is to be understood. One of the few examples of an explicit definition is proposed in one of the very most influential publications regarding the lean philosophy and its application to different industries, including construction:

> “The critical starting point for lean thinking is value. Value can only be defined by the ultimate customer. And it’s only meaningful when expressed in terms of a specific product (a good or a service, and often both at once) which meets the customer’s needs at a specific price at a specific time.” (Womack & Jones 1996; 2003, p. 16)

As will be discussed later in this thesis, such definition of value bears a number of implications if applied as a basis for identifying value (and hence also waste) in relation to construction.

It is important to be aware that this perception of value is very narrow, and that issues regarding notions of value have been subject to some critical debate in relation to lean construction (discussed later in this chapter).

### 3.2.5. Lean design and product development

While design has been subject to considerably less attention than production it has nevertheless been ascribed major importance in several dominating works, and the terms *lean design* and *lean product development* are often used synonymously. Some common features of lean design/product development in manufacturing industries

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46 Many publications on lean make – often to a considerable extent - use of Japanese terms. ‘Muda’ is used as referring to ‘waste’ and covers any kind of resource spent that does not directly add value as this is perceived by the end customer (see. e.g. Ohno 1988; Womack *et al.* 1990; Womack & Jones 1996).

- Design with focus on customer value and resource-efficient manufacturing;
- Strategic management;
- Simultaneous/concurrent design/development of different systems and subsystems;
- Cross-functional and cross-disciplinary design teams with strong and closely involved leadership;
- Production approach based on larger subsystems from fewer suppliers and a high level of supplier involvement in design/development processes.

The question of single- vs. multi-project management is emphasised as an issue of significant importance and has occasionally been referred to as a conceptual development ‘beyond lean’ (e.g. Cusumano & Nobeoka 1998). Related issues of cost/profit management; supply chain management, system’s-level optimisation, and built-in scope for continuous improvement have been further discussed by Cooper & Slagmulder (1997; 1999).

3.3. The transfer of a manufacturing philosophy from car production in Japan to construction in the West

The lean philosophy entered construction debate and practice a couple of years after it had gained momentum in western manufacturing industries. The application of the philosophy to construction was first discussed by Koskela (1992) who in the following year took part in establishing The International Group for Lean Construction (IGLC), a loosely organised and open “network of professionals and researchers in architecture, engineering and construction (AEC) who feel that the practice, education, and research of AEC have to be radically renewed in order to respond to the challenges ahead.”

Since Koskela published his report (1992) ‘Application of the New Production Philosophy to Construction’ work within the field that became known as ‘lean construction’ has studied and discussed a large variety of issues and aspects related to disciplines and activities of managing construction. Since then, some publications of this field have placed themselves within the discourse of the ongoing manufacturing and ‘lean’ debate while others have drawn on some of the ideas and developed these with respect to a construction context. Other contributions to the lean construction debate appear to have developed partly independently with lean construction occasionally being (re)translated in different ways and adapted to the contextual circumstances in which its different examples of application have been embedded. Finally, some lean construction publications represent a diversity of works that seem

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48 By the term “new production philosophy” Koskela referred to “an evolving set of methodologies, techniques and tools (…) Several alternative names are presently used to refer to this philosophy: lean production, JIT/TQC, world class manufacturing, time based competition.” (1992, in the report summary (without page number)). “… the new production philosophy, which is known by several different names (world class manufacturing, lean production, new production system) is the emerging mainstream approach.” (p. 5).
not to position themselves with apparent relation to ideas from the lean philosophy nor to tools specific for its practical application.49

Before turning to the discussion on the definitions of lean construction and a discussion on the previous research, it must be mentioned that the issue of lean construction has hitherto been the topic of rather few articles in leading research journals. In general the few examples of such articles have addressed individual issues or aspects of the lean construction debate.50 The low number of articles is especially significant when considering the broad scope of the field. However, there appears to be a development towards a higher frequency of publications in research journals and ongoing critical debate is emerging (discussed later). This indicates an increasing academic maturing of lean construction research and debate. Similarly few larger research reports, as e.g. doctoral theses, have been published. However, it must be acknowledged that some larger works, including some doctoral theses, have investigated individual issues or aspects addressed in the lean construction debate (some examples: dos Santos 1999; Ballard 2000a; CIB 2002; CII 2004; Tzortzopoulos 2004; Tsao 2005).

The large majority of titles on lean construction are conference papers from the annual conferences of The International Group for Lean Construction (IGLC). From a research perspective these are of very different (academic) quality: everything from very meticulously conducted research (that have sometimes been exposed to IGLC for broad feedback and enriching discussion before being submitted to leading academic journals), to discussion outlines, to contributions of personal opinion, and sometimes promotion of tool/methods/organisations by arguments not based on actual research. An obvious weakness of many papers published at conferences of the IGLC is a tendency of ‘self-referencing’ where publications are based fundamentally on other IGLC publications etc. or, when less pronounced, on a limited range of titles on construction management, production control and popular management literature. From a research position, this approach is highly problematic and such work often invalid as basis for further academic study (discussed in Chapter 2). Furthermore, it can be argued that construction is fundamentally a sub-set of human experience, rather than a completely separate phenomenon and must thus be studied not exclusively through construction literature but also through works of the disciplines.

49 Through the years The International Group for Lean Construction (IGLC) has provided wide room for debate on construction management issues, regardless of contributions conformity with conventional academic norms or conference concepts, and has thus provided a forum for discussions falling or expanding outside the more traditional and purely research-orientated networks, organisations and conferences. Opinions probably differ on this and it is arguably a question of interpretation. Since IGLC is a network and not a formal organisation with statutes, standing orders, secretariat, chairperson or other representatives consultable for an official position, this interpretation builds on a position explicitly adopted by one of the few continuously contributing members, Gregory A. Howell, director of the Lean Construction Institute. In a discussion running on the informal email network of IGLC (May 5th 2005) Howell justified the existence of IGLC by arguing the need for a forum where discussions, of academic and practical relevance, that fall outside the scope of other conferences, can take place: “This group [IGLC] has been aimed at figuring out together this new approach to managing work. We have welcomed ideas that sounded crazy or half baked at first because that is the way we started.”

50 Examples of articles in leading journals are: (Ballard & Howell 1998; 2003a); (Arbulu et al. 2003); (Tommelein et al. 1999); (Vrijhoef & Koskela 2000); (Formoso et al. 2002a; 2002b); (Thomas et al. 2002; 2003); (Ballard et al. 2003); (Choo et al. 2004); (Tsao et al. 2004); (Elfving et al. 2005); (Gil et al. 2005).
on which construction research draws (Hughes 1997; 1999). The above justifies the following questions regarding this thesis’ study on of lean construction: a) why only a selection of IGLC publications are touched upon while a large number are left without further discussion, and; b) why the research is based on publications from a large variety of academic disciplines and with emphasis on previous research into the better investigated field of lean production instead of commencing with lean construction as starting point. The logical consequence for this research will be to incorporate previous research and contributions of debate from a pure relevance perspective – regardless of label – while ensuring some degree of multidisciplinary representation.

3.3.1. The meaning of lean construction – different definitions

Similar to lean production, some confusion prevails regarding the definition and content of lean construction. As is illustrated in Table 3.3, different definitions (explicit and implicit) form the basis for discussion in a number of publications.

Table 3.3: Examples of explicit or implicit definitions/understandings/descriptions of lean construction.

<table>
<thead>
<tr>
<th>Publication</th>
<th>Definition/understanding/description of lean construction</th>
<th>Definition explicit?</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Koskela (1992)</td>
<td>Lean production applied to construction. Lean production is perceived as “the emerging mainstream approach” to main principles, ideas and techniques as Just-In-Time and Total Quality Control (p. 5-6). “Rather than defining a specific set of methods, these terms are loosely used to refer to an intensive use of the ideas of the new production philosophy.” (p. 8) “In various subfields of the new production philosophy, the following heuristic principles have evolved: 1. Reduce the share of non value-adding activities. 2. Increase output value through systematic consideration of customer requirements. 3. Reduce variability. 4. Reduce the cycle time. 5. Simplify by minimizing the number of steps, parts and linkages. 6. Increase output flexibility. 7. Increase process transparency. 8. Focus control on the complete process. 9. Build continuous improvement into the process. 10. Balance flow improvement with conversion improvement.</td>
<td>No</td>
<td>Koskela discusses the application of ‘the new production philosophy to construction’, concluding that theoretical and conceptual understanding was still incomplete, and the field under development. The term ‘lean construction’ is not applied in this publication.</td>
</tr>
</tbody>
</table>

51 Explicit in this table does not refer to exact formulations by the publications but to whether the publications explicitly explain what the author(s) mean or to what is referred, by ‘lean construction’ or if the interpretation listed in the table’s second column has been deducted from an analysis of the publication.
11. Benchmark.”
(p. 16)

Main sources\(^{52}\): (Monden 1983); (Shingo 1984); (Ohno 1988); (Womack et al. 1990).

| **DETR (1998)** | “The application of lean thinking (which describes the core principles of lean production, the generic version of the Toyota Production System) to construction.” | Yes | Report that appears to apply a largely one-sided view in accordance with interests of large corporate clients, as also criticised by Green (1999; 2000) and by Green & May (2005). |
| **Koskela (1998)** | Lean production applied to construction design and production. | Yes | In a discussion of lean production’s application to construction, the author focuses on underlying ideas of lean production, rather than specific practices. |
| **Green (1999a)** | Methods of lean production and Japanese manufacturing management applied to construction. | Yes | The article introduces research findings demonstrating negative HR aspects of Japanese lean production. Green argues that this has been ignored in the debate on lean construction which has recognised only the arguments favourable to the approach. |
| **Green (1999b)** | Lean production and lean thinking in construction. | Yes | The paper is written “self consciously from a critical perspective”, and argues that literature \(^{52}\) \(^{52}\) ‘Main sources’ here refer to the sources from which the individual publication’s perception of ‘lean’/lean construction appears to be adopted.
### Towards an understanding of ‘lean’

<table>
<thead>
<tr>
<th>Author(s)</th>
<th>Title</th>
<th>Year</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>Howell &amp; Ballard (1999)</td>
<td>Lean production and lean thinking in construction.</td>
<td>1999</td>
<td>This paper is a response to Green (1999b). It argues that ‘lean’ is a positive phenomenon in e.g. construction and that adoption of lean does not necessarily lead to a negative impact. It points out that Green’s criticism would also count for other management principles and approaches. The paper proposes that further research should aim to investigate how the benefits of lean can be gained in construction and how potential negative impacts can be avoided. The paper does not address Green’s criticism of lean-critical literature having been ignored in the lean construction debate. Interestingly it is stated that “Lean is about reducing waste but it has no intention or mechanism to add stress and it is unfair to make such a claim.” This is interesting when considering the many examples from manufacturing research – several even cited by Green (1999b) - having documented the opposite.</td>
</tr>
</tbody>
</table>
| Howell (1999) | “Lean construction:
- has a clear set of objectives for the | Yes | The paper concludes that “significant research |

---

53 The author has discussed this issue with Glenn Ballard, who explained that in his view any management approach (‘lean’ or not) can be abused and that the interests of management tends to override the interests of the worker unless the latter is protected by union or law. Disagreement may thus be smaller than it at first appears, and the exchange of views between Green and Howell & Ballard provides an example of the lean theme being discussed from radically different perspectives emphasising differently the importance of the lean approach itself vs. that of managerial enforcement.
delivery process,
• –is aimed at maximising the performance for the customer at the project level,
• –designs concurrently product and process, and
• –applies production control throughout the project.”

Lean construction is perceived as lean production applied to construction.

Main sources**: (Womack et al. 1990); (Koskela 1992).

| Seymour (1999) | A production system for dynamic projects where “a key technique for lean construction is the LP” [Last Planner System].  
Main sources**: (Howell & Ballard 1998); (Koskela 1999). | No |
| Ballard (2000a) | The approach of lean production and lean thinking adapted and applied to construction, with special emphasis on eliminating waste.  
Main sources**: (Shingo 1988); (Ohno 1988); (Womack et al. 1990); (Koskela 1992; 1999); (Womack & Jones 1996). | No |
| Howell & Koskela (2000) | The approach of lean production and lean thinking applied to construction and construction management.  
Main sources**: Alarcón (1997); Ballard & Howell (1998b); Koskela (2000). | No |
| Koskela (2000) | The application to construction of a general theory, addressing transformation and flow, as well as value dimensions of production.  
Main sources**: A wide range of sources. | No |

remains to complete the translation to construction of lean thinking.”

The paper proposes an ambitious agenda for research into system-wide application of lean construction tools. Ethnography, it is argued, provides a valuable methodological apparatus for further research.

Doctoral thesis investigating aspects of implementation of the Last Planner System to construction production and design.

The paper argues for a reform of project management understanding and practices, and identifies customer value aspects as underemphasised in lean construction practices but subject to increasing attention and developing in terms of understanding.

A Ph.D. thesis that has become a very important publication within the lean construction movement, whereas some appear to consider it a theory of lean construction per se. It is important to notice that this thesis studies whether it is possible to formulate a general theory for production and if such can be applied to construction for improved understanding.
3. Towards an understanding of ‘lean’

<table>
<thead>
<tr>
<th>Author (Year)</th>
<th>Description</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>Picchi (2001)</td>
<td>Lean thinking and adapted lean production principles applied to construction. ‘Lean’ is perceived on three levels (philosophy, system, and techniques) and a number of “lean core elements” are identified as relating to five lean principles (Womack &amp; Jones 1996): value, value stream, flow, pull, and perfection. Main sources**: (Womack et al. 1990); (Womack &amp; Jones 1996).</td>
<td>Yes</td>
</tr>
<tr>
<td>Green (2002)</td>
<td>Methods of lean production applied to construction with little acknowledgement of context or human resource implications. Main sources**: (Womack et al. 1990); (Womack &amp; Jones 1996).</td>
<td>No</td>
</tr>
<tr>
<td>Koskela et al. (2002)</td>
<td>”‘Lean’ is a way to design production systems to minimize waste of materials, time, and effort in order to generate the maximum possible amount of value.” (p. 211) “There are two slightly different differing interpretations of lean construction. One interpretation holds that the question is about the application of the methods of lean production to construction. In the contrast, the other interpretation views lean production as a theoretical inspiration for the formulation of a new, theory-based methodology for construction, called lean construction.” (p. 212) “A lean project delivery system is one and performance. The thesis concludes that a general theory can be formulated (which is not done in this thesis) and that it must simultaneously encompass three views of production: production as a process of transformation; as a process of flows, and; as a process of value generation (p. 25). The thesis does not define nor provide a theory for lean construction.</td>
<td>Yes</td>
</tr>
</tbody>
</table>
that is structured, controlled, and improved in pursuit of all three goals, i.e., the transformation/flow/value goals proposed by Koskela (2000). (…) all systems that pursue the TFV [Transformation, Flow, Value] goals are, in principle, lean delivery systems, though some will be leaner than others.” (p. 217).

Main sources: (Koskela 2000); (Ballard & Howell 1998); (Ballard 2000b).

| CIB (2002) | Lean construction, it appears, is discussed as consisting of a number of “lean construction principles” of which the most important are the following  
- reduce output variability;  
- improve flow reliability;  
- symbiotic relationships;  
- reduce cycle times; and  
- simplify work methods. |
<table>
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<tr>
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<tbody>
<tr>
<td>No</td>
<td>The report focuses relatively narrowly on productivity and does not include a single reference to literature on lean production, Japanese manufacturing principles or other basic work on issues of lean.</td>
</tr>
</tbody>
</table>

Main sources**: (Koskela 1992); (Ballard & Howell 1994); (Ballard & Howell 1995); (Ballard & Howell 1998); (Tommelein 1998); (Tommelein et al. 1999).

<table>
<thead>
<tr>
<th>Thomas et al. (2002)</th>
<th>“Lean construction refers to the application of lean production principles to construction. Lean production is an encapsulation of recent production management developments in manufacturing.” (p. 144)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>The article focuses on productivity and adopts a narrow perception of lean construction as concerning production management and control exclusively. The approach and conclusions of the article have been criticised and questioned by Howell et al. (2004).</td>
</tr>
</tbody>
</table>

Main sources**: (Koskela 1992); (Ballard & Howell 1994); (Ballard & Howell 1995); (Ballard & Howell 1998); (Tommelein 1998); (Tommelein et al. 1999).

<table>
<thead>
<tr>
<th>Construction Industry Institute (CII) (2004)</th>
<th>“Lean construction is the continuous process of eliminating waste, meeting or exceeding all customer requirements, focusing on the entire value stream and pursuing perfection in the execution of a constructed project.” (p. 5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>A large report with comprehensive empirical case study material. Productivity is the paramount issue studied.</td>
</tr>
</tbody>
</table>

A number of lean principles and sub-principles are identified and interpreted with respect to the construction context. Lean construction is perceived as lean production applied to construction.

Main sources**: (Womack et al. 1990); (Koskela 1992); (Womack & Jones 1996); (Ballard 2000a).

<table>
<thead>
<tr>
<th>Winch (2005)</th>
<th>Lean construction consists of a theory described by Koskela (2000) that supports application through the Lean project Delivery System (Ballard</th>
</tr>
</thead>
<tbody>
<tr>
<td>No</td>
<td>The paper is a response to (Koskela et al. 2004) who criticised economics-based approaches to</td>
</tr>
</tbody>
</table>
Towards an understanding of ‘lean’ PLB

BYG Bo Jørgensen (2006) 79

Main sources**: (Koskela 2000); (Ballard et al. 2002).

2000b; Ballard et al. 2002).

Main sources**: (Koskela 2000); (Ballard et al. 2002).

project management. For what comes to the understanding of lean construction it appears that Winch endorses mainly two works, (Koskela 2000) and (Ballard et al. 2002) - neither of which claim to represent lean construction at large - and implicitly accepts these as defining lean construction.

| Paez et al. (2005) | “Lean construction applies the lean philosophy to on-site, one-of-a-kind, complex operations for long-term improvement. (…) Lean construction and lean manufacturing conform to a socio-technical design with the same goals, activities, and workforce capabilities. They differ on the technical system that is suitable for each context.” (p. 243) | Yes | The article is somewhat inconsistent in its argumentation. It is implicitly suggested that lean construction cannot work without the application of the Last Planner System and daily Huddle meetings (and thus also that other tools cannot substitute these without the approach taken falling outside the authors’ definition of lean construction). This conclusion is not argued for, and contrary to arguments by e.g. Koskela et al. (2002). |
| Winch (2006) | Lean construction is approached as being represented on the theoretical level by the transformation/flow/value (TFV) theory (Koskela 2000), and on the applied level by practical tools as the Last Planner System (Ballard & Howell 1998) and the Lean Project Delivery System (Ballard et al. 2002). | Yes | The paper is a response to an invitation for debate from Koskela & Ballard (2006) who criticised economics-based approaches to construction project management, and suggested that project management should essentially be based on theories of production. |
| The Lean Construction Institute (LCI) (2004) | “Lean Construction is a production management-based approach to project delivery – a new way to design and build capital facilities. Lean” | Yes | To date no study has documented an example of a project executed in complete fulfilment of |

---

production management has caused a revolution in manufacturing design, supply and assembly. Applied to construction, Lean changes the way work is done throughout the delivery process. Lean Construction extends from the objectives of a lean production system - maximize value and minimize waste - to specific techniques and applies them in a new project delivery process. As a result:

- The facility and its delivery process are designed together to better reveal and support customer purposes. Positive iteration within the process is supported and negative iteration reduced.
- Work is structured throughout the process to maximize value and to reduce waste at the project delivery level.
- Efforts to manage and improve performance are aimed at improving total project performance because it is more important than reducing the cost or increasing the speed of any activity.
- ‘Control’ is redefined from ‘monitoring results’ to ‘making things happen.’ The performance of the planning and control systems are measured and improved.”

Table 3.3 illustrates that lean construction is no less clarified in terms of a commonly shared definition than what is lean production. The lack of a common definition for lean construction and ‘leaniness’, has been discussed by Green & May (2005) who found that lean construction and lean production are “variously understood as a set of techniques, a discourse, a ‘socio-technical paradigm’ or even a cultural commodity.” (p. 503). Based on an empirical study from the UK construction industry and interviews with authors of the so-called ‘Egan Report’ (DETR 1998), Green & May suggest that three models represent the practical adoption of ‘lean’ in construction: a lean model of ‘waste elimination’, ‘partnering’, and ‘structuring the context’. An important outcome of this research is that the findings support the view that lean construction, while highly diverse in interpretation and applied practice, is inspired by lean production rather than just a transferred copy of it.55 It is concluded that the meaning of lean construction is continuously renegotiated within localised contexts (p. 510).

While there is a great diversity of work that has addressed lean construction through many different approaches, a common feature appears to be the adoption of a project structure as the organisational basis for designing and making. It is also possible to make the observation that there has clearly been a development in debate,

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55 This relationship between lean production and lean construction has, as discussed above, previously been proposed by Koskela et al. (2002).

Bo Jørgensen (2006)
understanding and practice within the field of lean construction, which appears to follow a pattern that has some similarity to that of the development of debate on lean production as has been described by Hines et al. (2004) (discussed earlier). One indicator of development is that there has not only been a development of the debate itself, also positions of dominant individual contributors have moved. For example, this can be illustrated if considering the works of Lauri Koskela. Since he, as the prime mover, brought the lean philosophy into the construction debate Koskela has been one of the most productive authors within the theme of lean construction, where his main contributions have been within the area of production theory. In the beginning by discussing lean production as applied to construction (see. Koskela 1992; 1993; 1998), to studying the more fundamental issues of developing a general theory for production (Koskela 2000; 2001; Koskela & Kagioglou 2005) and the understanding of lean construction as a discipline inspired by, not copied from, lean production (Koskela et al. 2002).

Similar to the diffusion of lean thinking to manufacturing industries (Hines et al. 2004), the value focus has gained momentum only in recent years, which appears to have happened a little later than in the manufacturing debate, discussed by Hines et al. (2004).

The diffusion of the lean philosophy and approaches from car manufacturing in Japan to Western construction is illustrated in Figure 3.2.

3.3.2. Lean design in construction

In relation to construction, ‘lean design’ is considerably less discussed and investigated than production issues. While also lacking a universal definition, ‘lean design’ in construction is used as referring to approaches, principles and methods for managing processes of design and/or of product development. This theme will be discussed in the following (see 3.4.4 Design management).
3. Towards an understanding of ‘lean’

3.4. Conceptual framework for ‘lean’ application to construction

As discussed above, it appears to be difficult to achieve a clear picture of the exact meaning of lean construction and what it does and does not imply. From publications on lean construction it follows that research and debate has focused mainly on these specific themes.56

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56 This division should not be confused with the theme organisation of the International Group for Lean Construction. Currently (May 2006) the International Group for Lean Construction has 11 themes to function as an umbrella for the work within the network: 1) theory, 2) production planning and control, 3) product development and design management, 4) implementation and performance measurement, 5) supply chain management, 6) prefabrication, assembly and open building, 7) people, culture and
3. Towards an understanding of ‘lean’ PLB

BYG Bo Jørgensen (2006) 83

- The ‘lean’ philosophy and its application to the built environment;
- Production planning, control and management;
- Production system design, and construction project design
- Design management;
- Implementation.

These will be briefly introduced. However, the themes do overlap and it is therefore problematic to divide them under these five headings. However, in order to achieve a more readable overview some division/classification is necessary. It should be noticed that there are also several other themes that have been touched on in relation to lean construction, and that some of these may often be interwoven with the more in-depth discussed themes listed above. Examples are supply chain management; health and safety issues; communication; cooperation; cost management and control.

3.4.1. The ‘lean’ philosophy and its application to the built environment

This theme was first discussed by Koskela (1992), who investigated what he (then) referred to as ‘the new production philosophy’ and its application to construction. Few works have since discussed the entire philosophy, while many more publications seem to address more specific issues of construction-orientated application from the framework now generally known as lean production. Some examples are (Melles 1994); (Seymour 1996; 1999); (Koskela 2000); (Koskela 2001); (Picchi 2001); (Koskela 2004a); (Koskela & Kagioglou 2005).

Koskela’s doctoral thesis (2000) has received the most attention, cited extensively in publications discussing issues of ‘lean’ in construction. Koskela argued that efforts to improve production (of physical artefacts, e.g. buildings and other structures) suffer from the absence of a general theory of production, and he argued that such a theory would need to encompass three fundamental elements of transformation, process, and value. Koskela concluded that most production practice and research (in construction, manufacturing and other industries) has been dominated by a focus addressing production simplistically from a transformation perception, with process and value generation aspects being underemphasised.

3.4.2. Production planning, control and management

Within lean construction this theme has received the most interest and attention to date. Two issues have dominated debate and publications: The Last Planner System of Production Control (LPS) in particular, and questions regarding scheduling techniques and work structuring.

3.4.2.1. The Last Planner System of Production Control (LPS)

While many issues of ‘lean’ in construction have been examined only superficially, one topic has been widely addressed in research, discussion and practical application: Approaches and methods for addressing waste through reduction of variability and uncertainty, especially the Last Planner System of Production Control (LPS). This appears to have become the most popular measure in applied initiatives of lean construction. In some local or national environments LPS, it appears, have become
largely synonymous with lean construction (Green & May 2005; Jørgensen et al. 2005). The system was initially developed by Glenn Ballard and Gregory Howell in the early 1990s and refined through theoretical studies, experiments and experience gained during the rest of the decade. LPS builds on the principle of systematic reactive work planning executed on the lowest possible level in the hierarchy of planners. The last planner refers to the organisational function (person or group) whose planning releases work directly for execution by the workforce at operational level. Hence the planning conducted by ‘the last planner’ does not serve as direct input for any lower level planning or scheduling activities. The overall objective of LPS is to increase plan reliability and thus serve as a framework to address waste deriving from uncertainty and plan deviance.

A cardinal principle of the system is that only work with the necessary preconditions for execution fulfilled can be included in the weekly work plan. On the basis of this information the work plan is composed by the last planners, typically the foremen or superintendents on site. Thus LPS is essentially a pull-based production planning and control tool.

![Diagram of traditional push-based work planning](http://example.com/diagram.jpg)

**Figure 3.3:** The principle of (traditional) push-based work planning. - From (Ballard 2000a).

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57 One example is the case of Denmark.

58 Literature on such themes as production control, logistics management etc. generally distinguish between two principles for workflow regulation: push and pull systems. Under a push approach inputs (as such task assignments, materials, information, work force resources etc.) are released into a system on the basis of pre-planning, which in construction could be the master production schedule. In a pull system pre-planning is supplemented by a feedback mechanism ensuring that inputs are released into the system on the basis of its ‘de facto’ current state (amount of work in progress, available capacity etc.). Elaborate discussion of push/pull systems are provided by e.g. Hopp & Spearman (1996).
Towards an understanding of ‘lean’

BYG Bo Jørgensen (2006)

Figure 3.4: The principle of the (pull-based) Last Planner System, where a work is planned for execution on the basis of feedback from the current state of the production system. – From (Ballard 2000a).

Performance of the planning process is measured as percent planned completed (PPC) and failure to work according to plan is evaluated through a root-cause analysis\(^{59}\), a feedback system intended to support team learning and continuous improvement. The principles and function of LPS have been described in detail in a number of publications (e.g. Ballard 1994; 2000a; Ballard & Howell 1998; 2003b) and, from different perspectives, a number of studies have dealt with aspects of its practical application to construction assembly (e.g. Ballard 2000a; Ballard & Howell 1994; 2003a; Johansen & Porter 2003; Jørgensen et al. 2004a; 2004b) and a few also in connection with design management (e.g. Koskela et al. 1997; Ballard 2000a; Ballard 2002).

\(^{59}\) The ‘5 why’ technique (as recommended by Ohno (1988)) is commonly promoted for use in lean construction. The procedure is to trace the ‘root cause’ of a problem by investigating cause and effect up to five steps back to find the actual reason eventually behind a failure or problem. The idea is to prevent the problem from reoccurring by attacking the real source of the problem.
Aspects of LPS and its practical application have been investigated in a doctoral dissertation by one of the system’s originators, Glenn Ballard (2000a), and the detailed explanation and arguments shall not be repeated here. It should however be noted that the practical application of LPS often builds on partial implementation of the entire system which is commonly modified in response to certain project circumstances, while in other cases references to the LPS represent merely individual aspects such as planning of work at weekly site meetings with participation of foremen. Examples of such partial implementation are typical for lean construction in e.g. Denmark.

Yet few studies have systematically investigated the impacts of LPS implementation in different construction companies over time. One example is a quantitative survey and analysis conducted by Alarcón et al. (2005) who studied a full decade of LPS implementation in the Chilean construction sector.

An interesting observation regarding LPS is that it applies an approach that in several respects is fundamentally different from lean production approaches applied in e.g. the motor vehicle industry. Where initiatives of lean production aimed at reducing waste typically build on principles of extensively reducing throughput variability and
minimising buffers, LPS addresses waste mainly through reducing uncertainty, thus increasing plan reliability.

The main focus point of LPS is not a pursuit to eliminate volume throughput variability (i.e. amount of work completed over time). Considering the very nature of a construction project where different production tasks and assignments are done as the project progresses towards completion, it is impossible to avoid throughput variability. The LPS method builds on the assumption that while construction throughput variability cannot be eliminated, it can to a significant extent be managed by application of pull-based reactive work scheduling to increase plan reliability and reduce the workload variability.60

Where a cornerstone in lean production is the levelling of volume throughput, which enables the elimination (or drastic reduction) of buffers, LPS operates with buffers of ‘workable backlog’ as a means for levelling the construction workflow through buffering against unpredicted plan variation. This workable backlog/buffer is necessary for coping with unintended throughput and workload variability that no approach to construction project management has succeeded in reducing to a level where buffers can be completely eliminated. However, an intention of the LPS is to enable a more strategic application of buffers. If achieving increased plan reliability (and with transparency regarding the workable backlog) the supply chain will often be in position to reduce or eliminate a variety of other buffers related to individual operations, deliveries, task preparation etc.

It should be noticed that this difference between ‘assembly line lean production’ models of manufacturing industries, and the LPS for construction must be expected to imply fundamentally different impact on working conditions (discussed below).

3.4.2.2. Scheduling techniques and work structuring

A number of studies have discussed issues of activity scheduling and of structuring projects, assignments and tasks for the application of lean techniques to construction (design and production). For example structuring of task execution for optimising resource allocation (e.g. through optimising batch sizes and minimising buffers, inventories, and work in progress), achieving short production cycles etc. In the approach of the Toyota Production System and lean production this field is central to the pursuing of short lead times, continuous improvements etc. and has received much attention in the most popular publications as those of Monden (1994); Ohno (1988); Shingo (1988; 1989); Womack et al. (1990); Womack & Jones (1996), and in books on manufacturing engineering (e.g. Hopp & Spearman 1996).

Some examples of application in lean construction:

- Value stream analysis and/or mapping in construction supply chains (e.g. Arbulu et al. 2003);
- Work flow analysis (e.g. Ballard et al. 2003), and workflow scheduling and management (Tommelein et al. 1999; Huber & Reiser 2003; Kenley 2004);
- Work structuring (Choo et al. 2004; Sacks et al. 2003; 2005; Tsao et al. 2004; Tsao 2005);

---

60 This should not be understood as if the LPS ignores possibilities for levelling production throughput when possible. In phase scheduling (similar to other approaches to scheduling activities) it is commonly attempted to pursue obvious benefits of levelling activities as e.g. completion of floors, drywall and HVAC installation to be completed in a certain time period. Hereby production management can benefit from increased possibilities of levelling the labour resource and the demands on shared resources such as space and lifting capacity.

Bo Jørgensen (2006)

3.4.3. Production system design and construction project design
This theme is strongly interconnected and widely overlapping with the two previously discussed themes. More general questions of how to structure construction projects – (and recently also the degree to which these are to be approached as individual projects in the first place) – have been an issue throughout the past one and a half decade of lean construction experimentation, debate, and research. Issues of how to structure projects and production systems have been discussed on all levels. Some examples are:

• Supply chain management topics (Vrijhoef & Koskela 1999; 2000; Vrijhoef et al. 2003);
• Relational contracting (a special issue of the Lean Construction Journal on relational contracting (vol. 2, issue 2) is accessible at http://www.leanconstructionjournal.org);
• Whether project management theory should be based on theories of production or on theories of economics (Koskela & Howell 2002; Koskela et al. 2004; Koskela & Ballard 2006);
• Perceptions and approaches of construction as a project-based production system (Ballard 2005; Vrijhoef & Koskela 2005; Koskela & Ballard 2006; Winch 2006).

The relatively little (when comparing to that of lean production/manufacturing) critical debate on productivity advantages of lean application to construction has largely revolved around issues of production system design and its implications (discussed later).

3.4.3.1. The Lean Project Delivery System
There are few examples of lean construction systems addressing the system’s perspective of construction projects. The best known example is the Lean Project Delivery System (LPDS) which suggests a systematic application of lean approaches to all project phases. It must be acknowledged that the system is still under development and though some tools are relatively well investigated (e.g. production control through use of the Last Planner System, see above), the LPDS does not yet offer a complete methodology for its practical application. It does however provide a practical framework/overview over the understanding from which its originators approach construction project delivery and pursue the development of practical methods. LPDS was first proposed by Ballard (2000b) (see Figure 3.6), and has since been extended into encompassing also the use phase (Koskela et al. 2002) (see Figure 3.7).
3. Towards an understanding of ‘lean’

BYG Bo Jørgensen (2006)

Figure 3.6: The Lean Project Delivery System (from Ballard 2000b).

Figure 3.7: The Lean project Delivery System in combination with a feedback loop from facility use (from Koskela et al. 2002).
3.4.4. Design management

Publications on design management in relation to lean construction generally adopt the term *lean design* or, emphasising that they are specifically addressing the management aspects, with the term *lean design management*. In general these can be said to address one or both of two categories:

a) publications discussing methods, tools and initiatives addressing *waste* or promoting efficiency in the producing of the design itself and/or in resource utilisation across the supply chain on project level; and

b) publications addressing directly *customer value* aspects other than those affiliated with consumption of resources (for delivering the individual project) and completion/delivery times.

The first category is considerably better represented than the last. Examples of publications from this category address the structuring of design tasks in order to avoid negative iteration in design, e.g. through use of design structure matrix (DSM) (Koskela *et al.* 1997; Austin *et al.* 2000; Hammond *et al.* 2000; Choo *et al.* 2004) or application of small batch and/or pull techniques (Ballard & Koskela 1998; Tzortzopoulos & Formoso 1999; Ballard 2000c; 2002; Ballard & Zabelle 2000). A noticeable part of the publications within this category are concerned with the application of LPS to design management. This particular issue has been studied and discussed in the most detail by Ballard (2000a; 2002).

Publications directly addressing customer value are few but the field appears to be gaining increasing attention. Examples of direct customer/client value aspects discussed relate to management of project definition processes (some examples are: Whelton 2004; Emmitt *et al.* 2004; 2005), and application of ‘design to target cost’ approaches to construction (Nicolini *et al.* 2000; Ballard & Reiser 2004; Kern & Formoso 2004; Jørgensen 2005; Granja *et al.* 2005; Ballard 2006). In relation to this thesis, target costing techniques that are known from lean manufacturing, are of particular interest because they address simultaneously four issues that are central to the lean philosophy and represent critical parameters of any construction project, namely *value, cost, profits* and *design/construction integration*. A basic introduction to the principles of designing to target cost and to considerations for their application to construction design can be found from (Jørgensen 2005).

The lack of explicit or clear definitions of what is meant by ‘lean design’ is no less noticeable than the missing clarity regarding the conception of ‘lean construction’ (discussed above in 3.3.2 Lean design in construction). Many publications have discussed design in relation to lean construction, but it is in the most cases not clear when and if authors discuss ‘lean design’, ‘lean design management’ or e.g. ‘design for lean construction’ and it is not clear if such terms are used to describe different phenomena.

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61 From a review of ‘lean design’ management literature in construction (primarily conference papers of the International Group for Lean Construction) Kestle & London (2002) conclude that hitherto much of the lean design management research had been concerned primarily with sequential production while only a few authors had explored a more sociological design management approach.

62 Target costing principles applied by Japanese lean manufacturers have been elaborately discussed by Cooper & Slagmulder (1997; 1999) who illustrates issues of practical application with a large number of small case studies (from Japan). Publications on target costing for construction appear to draw heavily on publications of these authors.
Different definitions/understandings/perceptions of the design theme in the area of lean application to construction are illustrated in Table 3.4 (below).

Table 3.4: Examples of definitions/understandings/perceptions of design in relation to lean application to construction (‘lean design’, ‘lean design management’, ‘design for lean construction’ etc.). This extract/selection covers both frequently cited as well as less cited academic articles and conference papers etc. that address the theme of lean in construction from a variety of perspectives. – The table includes a few publications where it is not clear if they in fact discuss design from a lean perspective or not, but that are commonly cited in later publications on ‘lean’ in construction design/production.

<table>
<thead>
<tr>
<th>Publication</th>
<th>Definition/understanding/perception of ‘lean’ approach to design (in relation to construction)</th>
<th>Explicit definition of ‘lean design’*</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Huovila et al. (1994)</td>
<td>“Design can effectively be conceptualised within the lean production paradigm (…) seeing any design process simultaneously as: • Conversion; • Flow; • Value generation.” (p. 150)</td>
<td>Yes</td>
<td>Early conference paper from the International Group for Lean Construction (reprinted in: (Alarcón 1997)) discussing approaches of ‘fast tracking’ and ‘concurrent engineering’ from the perspective of their application to construction.</td>
</tr>
<tr>
<td>Koskela et al. (1997)</td>
<td>Not clear.</td>
<td>No</td>
<td>A commonly cited IGLC conference paper (titled ‘Towards Lean Design Management’) which argues that design activities generally are pushed away from optimal sequence and that this leads to low performance. A case study of implementing the Last Planner System to design management is presented along with positive results. The question of active client involvement is raised as an important issue deserving more attention. It is concluded that more future research is needed. The term ‘lean’ is not used in the text.</td>
</tr>
</tbody>
</table>

* Explicit in this table does not refer to exact formulations in the publications but to whether the publications explicitly explain what the author(s) mean, or to what is referred, by ‘lean design’ or if the definitions listed in the table in the second column can be deducted from the analysis of the publication.

*** ‘Main sources’ here refer to the sources from which the individual publication’s perception of ‘lean’/lean construction appears to be adopted.
3. Towards an understanding of ‘lean’

<table>
<thead>
<tr>
<th>Author(s)</th>
<th>Description</th>
<th>Key Terms</th>
</tr>
</thead>
<tbody>
<tr>
<td>Koskela (1998)</td>
<td>Lean production approach applied to construction design. – Concurrent focus on conversion, flow and value generation aspects.</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td>Main sources**: (Shingo 1988); (Womack et al. 1990).</td>
<td></td>
</tr>
<tr>
<td>Melhado (1998)</td>
<td>Design for lean construction and ‘lean thinking design’.</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td>Main sources***: (Koskela 1998).</td>
<td></td>
</tr>
<tr>
<td>Tzortzopoulos &amp; Formoso (1999)</td>
<td>Application of lean construction principles to design.</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td>Main sources***: (Huovila et al. 1994); (Ballard &amp; Koskela 1998)</td>
<td></td>
</tr>
<tr>
<td>Ballard (2000c)</td>
<td>Unclear. – ‘Lean design’ is referred to as something construction should move towards but which requires a better understanding of both value generation and waste reduction in design. A number of initiatives (application of set-based design and sequencing work using a design structure matrix etc.) are mentioned as lean design techniques.</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td>Main sources***: Various.</td>
<td></td>
</tr>
<tr>
<td>Ballard &amp; Zabelle (2000)</td>
<td>Lean design is understood as an integral element in the Lean Project Delivery System (see. Ballard 2000b). “Lean Design phase begins once project Definition has aligned purposes, criteria, and concepts. It ends when product and process design have been produced and themselves brought into alignment with the Project Definition elements.” (p. 1)</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>White paper from the Lean Construction Institute (LCI). It presents recommended tools and techniques, and provides an overview of ongoing LCI research into lean design.</td>
<td></td>
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</table>

The term ‘lean’ is not used in the text.
A number of tools and techniques for managing design within the Lean Project Delivery System are presented and discussed:

- Cross Functional Teams
- Pull Scheduling
- Reduce design batch sizes
- Design Structure Matrix
- Strategies for Minimizing Negative Iteration
- Set Based Design
- Share incomplete information
- Work Structuring
- Simultaneous product and process design
- Shared geometry; unified modeling
- Shift detailed design to specialty contractors
- Produce and inspect outputs based on a definition of quality as ‘fulfillment of purpose’, not ‘conformance to requirements’
- Last Planner system of production control.

**Main sources***: Various.

<table>
<thead>
<tr>
<th>Author</th>
<th>Description</th>
<th>Source</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ballard (2002)</td>
<td>Lean production / Toyota Production System as the model for a way of designing and making things (p. 284)</td>
<td>Ballard (2002) Lean production / Toyota Production System as the model for a way of designing and making things (p. 284)</td>
<td>No</td>
</tr>
<tr>
<td>Freire &amp; Alarcón (2002)</td>
<td>“Lean design is the application of lean production principles, which promote the elimination of waste and non-value adding activities in processes, to engineering and design. It considers three perspectives to describe the design process … conversion, flow, and value generation.” (p. 249)</td>
<td>Freire &amp; Alarcón (2002) “Lean design is the application of lean production principles, which promote the elimination of waste and non-value adding activities in processes, to engineering and design. It considers three perspectives to describe the design process … conversion, flow, and value generation.” (p. 249)</td>
<td>Yes</td>
</tr>
<tr>
<td>Brookfield et al. (2004)</td>
<td>“The purpose of lean design is to improve the ‘manufacturability’ of a product through attention to information coordination and flows at the outset of the project, and the development of ‘design for production’ solutions to technological, functional and operational requirements. It is here in</td>
<td>Brookfield et al. (2004) “The purpose of lean design is to improve the ‘manufacturability’ of a product through attention to information coordination and flows at the outset of the project, and the development of ‘design for production’ solutions to technological, functional and operational requirements. It is here in</td>
<td>Yes</td>
</tr>
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</table>
3. Towards an understanding of ‘lean’

The upstream phases that value is added and subsequently embedded in the production information. Fundamental to the lean design approach is the design of appropriate communication structures before any design work commences. As a management process, it may have the following characteristics:

- Understanding the value streams by which value is delivered;
- Identifying value from the customer’s point of view;
- Achieving synchronous flow within work processes as waste is removed;
- Achieving pull so that no information is delivered until it is needed;
- Perfection- recognizing that improvement needs to be constantly pursued.”

Main sources***: (Womack & Jones 1996); (Alarcón 1997).

<table>
<thead>
<tr>
<th>Author(s)</th>
<th>Description</th>
<th>Case Study</th>
<th>Sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>Emmitt et al. (2005)</td>
<td>Lean design management understood as design management that enhances client, user and stakeholder value(s) while reducing waste in the overall project perspective.</td>
<td>No</td>
<td>Main sources***: Not clear.</td>
</tr>
<tr>
<td>Tilley (2005)</td>
<td>“Lean Design Management (LDM) - the introduction of “lean production” principles to the process of design - has been promoted as a new paradigm by which the design process can be made more efficient and better quality outcomes achieved. (…) the ultimate aim of any lean design management strategy should be to maximize overall client and user value from the project.”</td>
<td>Yes</td>
<td>Main sources***: (Koskela 2000).</td>
</tr>
</tbody>
</table>

3.4.5. Implementation

This theme is very wide and has been discussed in a large number of publications. On the overall, implementation issues – in all their contextual complexity - have not yet been studied thoroughly, and many IGLC conference papers appear to either aim for promotion or call for feedback. Seymour & Rooke (2001) have proposed that ethnography should be given more attention in future studies and practical initiatives into implementation of lean construction.
Application of tools (the Last Planner System in particular), have dominated studies into implementation (discussed above), but yet few studies have looked into the wider impacts of lean diffusion beyond project or company level.

Examples of implementation studies can be divided under three categories:

- Empirical studies reporting different findings regarding project or process performance in connection to lean initiatives. Recent examples are provided by: CIB (2002); Thomas et al. (2002; 2003); Salem et al. (2004); Court et al. (2005); Aláircon et al. (2005).
- Qualitative studies investigating implementation and diffusion processes, reporting applied practice in comparison to formal procedures, identifying e.g. obstacles and possibilities regarding implementation. Recent examples are provided by Miller et al. (2002); Johansen & Porter (2003); Johansen et al. (2004); Jørgensen et al. (2004c; 2004c; 2005); Green & May (2005).
- Methodological considerations for studying, developing and implementing lean construction. Some examples are: (Seymour 1996; 1999); (Seymour & Rooke 2001).

Regarding the second category, empirical studies of lean construction implementation processes have highlighted considerable implementation challenges deriving from contextual circumstances of the construction industry, such as cultural issues, institutionalised practices, organisational structures, conflicts of interests etc., similar to lean implementation problems encountered in other industries (discussed below). There appears to be an increasing interest in investigating and developing lean construction implementation in relation to organisational context. This development seems to go along with an increased momentum for research into non-production specific lean construction issues.

### 3.5. Lean construction critique

While the promotion of ‘lean construction’ has been very visible in countries such as e.g. Denmark, the USA and the UK, critical debate has been scarce. While success stories - reporting significant or even revolutionary results following the application of ‘lean’ approaches/tools/systems in manufacturing industries - have been more or less heavily promoted (e.g. through DETR 1998), the extensive critical debate on ‘lean production’ has been scarcely reflected in publications discussing the transfer and application of lean approaches to construction. Exceptions are the works by Stuart D. Green (1998; 1999a; 1999b; 2000; 2002) and Green & May (2003; 2005). One of the main contributions of these publications is a substantiated critique that research which is critical of the claims made by lean (production) proponents has been ignored in the (lean) construction debate. While this bias of publications addressing ‘lean construction’ is highly problematic, this thesis argues - as will be substantiated later in this chapter – that it must be recognised that:

a) many of the issues of ‘lean production’ identified by research as problematic are contextually bound to the application in manufacturing industries, and the

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64 Among the works of Green this conference paper (1999b) is exceptional in the respect that it has received a direct response from proponents of ‘lean construction’. Apart from commenting on the lack of critical debate, Green questions the transferability of ‘lean production’ from its Japanese origin to a Western context while also accusing the ‘lean’ approach for imposing heavy negative impact to the wellbeing of employees. In response to Green’s scepticism Howell & Ballard (1999) state that negative consequences do not necessarily need to follow application of ‘lean’ initiatives and principles to construction, and that negative impacts are not affiliated with lean principles _per se._
critical arguments raised are not always relevant in relation to the issues addressed by publications focusing on lean application to a construction context; and that

b) a large portion of publications on ‘lean construction’ are concerned with one or few aspects of limited extent and do not address a larger perspective that involves the most heavily disputed questions of the much richer ‘lean production’ debate.

In the following a brief introduction to the comprehensive critique that has been directed towards lean production and western adoption of Japanese management concepts and techniques will be given before discussing the critique that has been addressed to lean construction specifically.

3.5.1. Lean production/manufacturing critique

As was illustrated above, an extensive body of research has discussed ‘lean production’ as a concept, examined examples of its practical application, and/or investigated specific issues addressed by ‘lean production’.

It is no overstatement to conclude that much research has been very critical regarding the credibility of the claims made by (especially) Womack et al. (1990) and several other proponents of ‘lean’. Claims for the general superiority of ‘lean production’ over all other systems or approaches have been convincingly rejected and a number of severe negative side effects of ‘lean production’ documented (Berggren 1990b; 1993a; 1993b; Cusumano 1994; Jürgens 1995; Morris & Wilkinson 1995; Wilkinson et al. 1995; Williams et al. 1995; Katayama & Bennett 1996; James-Moore & Gibbons 1997; Benders & van Bijsterveld 2000; Benders & van Bijsterveld 2000; Lewis 2000; Boyer & Freyssenet 2001; 2002; Cooney 2002). In general (critical) research has acknowledged that measures promoted under the label ‘lean production/manufacturing’ (or ‘Toyota Production System’) can be advantageous, depending on circumstances, and it has also substantially enriched the understanding of the impacts of ‘lean production’. In addition to other general characteristics of popular management literature addressing lean, critical research has highlighted extensive ambiguity, contradictions, omissions, and unsubstantiated conclusions that are found to be highly open to criticism.

Research has mostly addressed the following points of criticism:

- The basic quality and reliability of popular literature that has dominated the broader debate on ‘lean production’ and its diffusion has been questioned and widely disregarded. Especially ‘The Machine that Changed the World’, (Womack et al. 1990) has been the extensively criticised by e.g. Berggren (1993a; 1993b); Williams et al. (1995); Kieser (1997); Benders & van Bijsterveld (2000) and Boyer & Freyssenet (2001; 2002). Considering this publication’s impact on the setting of ‘lean’ as a leading management fashion of the 1990s and early 2000s it is not surprising that this publication has received the most criticism. It will be too great a task for this thesis to repeat all the aspects, citations and conclusions from this publication that have been subject to criticism. - For a brief introduction to the most obvious points of criticism, concise overviews are provided by Berggren (1993a) and Jürgens (1995). An example of a publication that has been critically debated within
3. Towards an understanding of ‘lean’

lean construction is ‘*Lean Thinking*’ by Womack & Jones (1996) that has been criticised by Green (1999a), Koskela (2004a)\(^{65}\), and Green & May (2005).

Also other prominent lean publications have received significant criticism, but few have been criticised within the debate of lean construction. While *The Machine That Changed The World* has received the most criticism, it is worth mentioning that titles as e.g. (Ohno 1988) and (Shingo 1988), books that have been very influential in both lean production and lean construction and are still today commonly cited as references to practices of Toyota, are highly criticisable from a research point of view. Both are essentially popular management titles and make extensive use of anecdotal arguments and references to own work, experiences and publications. In both examples non-verified anecdotes from the authors’ careers are heavily used as evidence for the arguments presented. Especially the work of Shingo (1988) is normative and prescribes an entire system and the management action for practical application. If taking literally all arguments and claims of Shingo it is often difficult to see their relevance for production management in a western context. The gap between the book’s management recommendations and the organisational and political reality of many western European labour markets is carved in stone by Shingo’s injunction that companies *must* prevent the formation of labour unions but instead arrange for company controlled workers’ councils to be organised in a fashion that these can serve to facilitate communication between company and workforce.\(^{66}\)

- The lean production model described by Womack *et al.* (1990) has never become the dominant production of the Japanese industry at large as is commonly claimed (Berggren 1993a; Lillrank 1995; Cusumano 1994; Katayama & Bennett 1996; Cooney 2002; Hines *et al.* 2004).

- The utmost importance of context and its decisive role has been widely ignored in publications dominating the diffusion debate. Some of these trend-setting publications have even explicitly disregarded the importance of context regarding the general applicability and advantageousness of ‘lean’ adoption (Berggren 1993a; Jürgens 1995; Williams *et al.* 1995; Kieser 1997; Lewis 2000).

- The implicit assumption that elimination of waste and enhancement of value is the most advantageous strategy for achieving competitiveness and profitability cannot be generalised (Berggren 1993a; 1993b; Cusumano 1994; Katayama & Bennett 1996; Lewis 2000; Boyer & Freyssenet 2001; 2002).

- It has been argued that the cross-national comparison of production data - through which lean production was promoted by Womack, Jones & Roos - is highly misleading, is not always factually correct, contains omissions of

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\(^{65}\) Koskela acknowledges the publication as a “business book” for inspiration and his critical discussion of the book is from the perspective of research.

\(^{66}\) Several of the books here criticised are, in spite of their obvious weaknesses, nevertheless appreciated by the present author since they do provide inspiring views and commonly overlooked methods addressing the theme of productivity and waste elimination/reduction.
It has been argued that lean production (which is after all still a volume production) provides an unsuitable approach for many manufacturers operating under conditions that do not fulfil the preconditions needed for the use of lean techniques (Berggren 1993a; Cusumano 1994; Jürgens 1995; Lillrank 1995; Katayama & Bennett 1996). The lean concept itself does not encompass the important influence of social and political institutions on enterprises and the procedures through which supply chains operate (Jürgens 1995; Williams et al. 1995; Cooney 2002).

The application of ‘lean production’ in Japan and in the West has caused significant negative side effects that have been documented in a number of studies. Especially research into working conditions and other HR aspects has revealed negative side effects resulting from practices of lean production. Empirical studies have indicated that procedures of lean production have come with a high price for Japanese industrial workers who work under very hard and stressful conditions and enjoy rights inferior to those of workers in western industrialised countries (e.g. Dohse et al. 1985; Briggs 1988; Berggren 1990; 1993b; Sullivan 1992; Jürgens 1995; Williams et al. 1995). For instance: unpaid and non-voluntary overtime work is a competitive advantage to Japanese car manufacturers that has been widely ignored in lean-promoting productivity comparisons between Japanese and western car manufacturers (Dohse et al. 1985; Berggren 1990; 1993b; Jürgens 1995; Williams et al. 1995). Other studies have discussed the consequences of the transfer of lean production principles from Japan to the West and found that adoption of these principles have often resulted in worsened working and employment conditions for production workers (Berggren 1990; Wilkinson et al. 1995; Benders 1999; Benders & van Bijsterveld 2000). Increased pollution (Cusumano 1994; Katayama & Bennett 1996) and large lean producers’ dominance and pressure enforced upon small suppliers are occasionally raised as problematic issues.

3.5.1.1. General considerations on the transfer of Japanese management innovations to alien environments

In addition to research addressing specifically the lean area, a wider discussion concerns the overall theme of interpreting and transferring management innovations from Japan to the West. Bearing in mind the diversity in perception of lean production, as was illustrated in Table 3.1, it can be argued that the debate on ‘lean’ in construction and other industries deserves more attention to be paid the question of coherence between actual practices in Japan and the western perception of the Japanese production and management systems that often serves as inspiration for management debate in the West.

Research into these issues suggests the existence of an often significant mismatch between the procedures and policies that Japanese companies are reported to practice and what is actually taking place. Western analysis and interpretation of aspects of Japanese organisation and systems is one thing, and the rhetoric of Japanese
companies - whose explanations appear to be essential to the western images of Japanese practices - is another (Briggs 1988; Sullivan 1992). Some publications call attention to how statements and official policies regarding work and employment conditions often contradict existing practice (Dohse et al. 1985; Briggs 1988; Wilkinson & Oliver 1989; Sullivan 1992; Jürgens 1995; Williams et al. 1995). It should be emphasised that the extent of these contradictions cannot all be ascribed as intentional manipulation from the Japanese organisations, but derives also from deep national and cultural differences in communicating organisational questions which may mislead Western authors and lead to misinterpretation of statements made by Japanese managers (Sullivan 1992).

Features of the Japanese management systems appear to be viewed differently in Japan and the West. Where in the US and Europe ‘participation’, ‘employee involvement’, ‘self-management’ and ‘team organisation’ appear to be seen as ways of empowering the work force, the Japanese involvement of employee teams is in fact typically restricted to the providing of suggestions for process improvement through structured quality control or kaizen (continuous improvement) circles (Klein 1989; Jürgens 1995).

The claim that there exists what can be called a Western over-interpretation of official Japanese organisation policies is supported by a number of titles studying closer the de facto organisation by Japanese lean producers. In a study of the transfer of Japanese management styles in US transplants of car and electronics industries, Kenney & Florida (1995) report that job security policies were applied to a considerably smaller extent than what the responsible Japanese managers had claimed. Based on empirical research Jürgens (1995) and Benders & van Bijsterveld (2000) found that contradicting claims made by much popular literature (e.g. Womack et al. 1990)67, the organisational structures of manufacturing plants of Toyota Motors in Japan are highly hierarchal and with a small span of control on the shop floor. Research into work and employment practices of Toyota and other Japanese car manufacturers generally suggest that organisational hierarchy and a rigorous factory regime are parts of the measures applied for managing and keeping production lean (Dohse et al. 1985; Wilkinson 1992; Berggren 1990; 1993a; 1993b; Jürgens 1995; Morris & Wilkinson 1995; Wilkinson et al. 1995).

Klein (1989) draws attention to the broader questions related to the human costs of management reforms aimed at imitating Japanese practices. She proposes a pragmatic approach to implementation, an approach that does not ignore that e.g. JIT principles and connected management practices have a stressing effect on production workers and in fact restrict their possibilities for influencing workplace decisions.

If accepting the above conclusions, one must also conclude that an obvious weakness of publications describing practices of Japanese organisation concepts is that they generally do not report in sufficient detail how the data has been collected, e.g. how

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67 Womack et al. (1990) state that: “the lean manufacturers, which operate without much of the hierarchy we find in Western companies, (…)” (p. 199). This sentence doesn’t say much but can be interpreted in different ways, e.g. as expressing that the Japanese hierarchy is different from that of the West, that formal hierarchal layers are fewer, that organisational hierarchy in Japan is less rigid in its function, or that the hierarchy by Japanese lean manufacturers is smaller than in the West. Implicitly Womack et al. (1990) and other work promoting Toyota’s Japanese plants as a positive role model (e.g. Sugimori et al. 1977; Liker 2004) seem to adopt the latter interpretation of Toyota’s organisational structures.
observations have been weighted in comparison to information provided by company representatives. Lean promoting publications describing in most detail the data collection supporting their arguments (e.g. Womack et al. 1990; Cooper & Slagmulder 1997; 1999) rely heavily on information provided by the management of the organisations studied, and they do not refer to any examples of more comprehensive critical investigations (e.g. through ethnographic or anthropological research methods) for establishing deeper and more thoroughly validated descriptions of the practices studied.

Such observations are important in relation to the assessment of the discussion on lean approaches to construction, because this discussion has set off taking lean production publications as the conceptual starting point. While the transferability of Japanese lean principles and methods to the built environment have been continuously discussed since (Koskela 1992), there has yet been little concern about these phenomena’s actual conformance with the reality in Japanese manufacturing. The findings above suggest that this issue deserves wider attention in the lean construction debate.

### 3.5.2. Critical debate on Lean construction

In comparison to lean production, lean construction is significantly less thoroughly researched. Where lean production has given rise to much critical debate, publications discussing critically lean construction have been relatively few and isolated, and there has been little actual debate about potential benefits versus disadvantages of lean construction.

In main construction research journals there are few previous examples of polemic academic discussions on findings and conclusions of publications investigating lean construction. Works of the self-declared critic Stuart D. Green (discussed below) have been the perhaps most visible exceptions.

In the following shall be given four examples of debate with exchanges of view regarding four different issues that, it can be argued, are of high relevance to future research into lean implementation in construction. These examples are:

- HR aspects of lean construction - critique by Green;
- Questions of point of focus in lean construction – critique by Thomas et al.;
- Economics- or production-based theories as the basis for theory development for construction project management – critique by Winch;
- Oversimplified perception of value.

#### 3.5.2.1. HR aspects of lean construction – critique by Green

Stuart D. Green has criticised or questioned lean construction and/or its promotion in a number of publications. The main points of criticism raised by Green are that:

- lean construction has been promoted from a one-sidedly positive view\(^{68}\) and that sufficient evidence of lean construction’s overall advantages is lacking (Green 1998; 1999a; 1999b; 2000; 2002; Green & May 2005);

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\(^{68}\) Researching construction management from a self-consciously critical position, Green also directs this criticism towards other popular management initiatives promoted for application to construction.
Towards an understanding of ‘lean’

Publications promoting lean construction have ignored the research that has raised concern over negative effects following application of lean production in the manufacturing industries (Green 1999a; 1999b; 2000; 2002); promotion of lean construction has drawn heavily on arguments from questionable popular management literature and demonstrated little consideration of context (Green 1999a).

The intention is not to repeat all Green’s arguments here. However, two issues deserve mentioning - and critical discussion:

One is that little debate seem to have followed Green’s well argued criticism, however (Green 1999b) received a direct response (Howell & Ballard 1999), but an actual debate over the substance in Green’s critique has never taken place and the discussion appears to have essentially been a ‘for-or-against controversy’ (see Table 3.3’s discussion of lean construction definitions).

The other issue that must be acknowledged is that while Green presents a strong argument when criticising the lean construction debate for adopting positive arguments from publications on lean production and ignoring research highlighting negative aspects of lean production, it is not given that the negative impacts of lean production necessarily transfer to lean construction. Some studies have revealed how the application of lean practices implied a deteriorating effect on HR conditions in manufacturing (discussed above) but context must be considered before concluding that outcomes of lean implementation, positive or negative, can be generalised across business sectors.

In the critique of lean production JIT procedures, extensive visual control, and increasingly trimmed production tact times have been blamed for causing stress and for reducing employee control over the work process on the expense of work variety, job satisfaction etc. (e.g. Dohse et al. 1985; Wilkinson & Oliver 1989; Berggren 1993a; 1993b), but such procedures have not been applied to construction (which still, to a considerable extent, includes elements of craft production) to anywhere near the extent seen in e.g. car manufacturing. In contrast to industrial manufacturing, construction assembly is largely a process of ‘moving the production system through the product’ which limits the extent to which the division of work can be successfully broken down into very small and thoroughly specified micro-activities and subtasks as is the case of (lean) car manufacturing at e.g. Toyota as it has been described by Ohno (1988), Shingo (1989) and Liker (2004). If also considering the nature of construction production, and its organisation around projects which is commonly accepted as a basis for lean construction (Koskela et al. 2002), it is not justified that lean initiatives in construction will naturally result in exactly the same problems (and benefits) as have been encountered in repetitive lean manufacturing where constantly reduced tact times and increased physical and psychological work pressure have been found to cause problems to the wellbeing of workers in e.g. the auto industry. Apart from the rigorous factory regimes and harsh working conditions of prominent lean car manufacturers, the points of HR and health/safety related criticism of lean production that have been the most elaborately addressed are the impacts of JIT, single-piece flow with visual monitoring/control, non-/low stock production, and of unceasing demands for reduced tact time. Critique has highlighted that such
procedures have a significantly stressing effect\(^69\) on the individual worker that, on top of this, is forced to work overtime whenever necessary to compensate for lost production time which frequently occur in a production not shielded by buffers.\(^70\)

It is beyond the scope of this thesis to discuss all procedures known from lean construction with respect to their HR implications and to compare the results with findings from research into lean production. However, it is relevant to consider further applied practices of lean construction in comparison with those of lean production. Since the Last Planner System appears to have become the internationally best known practice of lean construction, and since LPS in some countries (e.g. Denmark) is commonly considered largely synonymous with lean construction, it is expedient with a few remarks on this particular lean construction tool in comparison to criticised practices of lean production (see above).

In comparison to these practices of lean production, the LPS takes a very different approach to waste reduction/elimination. The issue central in the criticism of HR implications of lean manufacturing is that the reduction of variability, through which the techniques applied serve to eliminate waste, has come with a high price for the workforce which needs to exhibit extreme flexibility to compensate for a ‘lean’/’fragile’/’non-buffered’ production system. Compared to mass/volume production in manufacturing industries (where buffers protect a stable workflow from impact of variability), construction is characterised by high variability that, with various success, is levelled by flexible manning strategies and a flexible workforce that can absorb variability by forcing the pace, working overtime etc. when necessary to compensate for lost productive time. Opposite to lean production techniques as JIT and single-piece flow, that eliminates waste by removing buffers, the LPS utilises buffers (‘workable backlog’) strategically with the aim to reduce workflow variability and thus increase predictability and plan reliability, hereby reducing the risk that the workforce will suffer disadvantage from plan failure. Principally two types of variation in production and work flow exist: natural variation and unintended variation. It is only the latter that the workable backlog helps buffer. Thus the workable backlog is no ‘bullet proof’ warranty against irregularity in production flow requiring some flexibility from the workforce. It can in fact only help avoid the loss of capacity utilisation (which under piece-rate systems commonly imply that the workforce bear a salary loss) when alternative work is not available, and can help maintain sequence only when tasks on production plans (scheduled work as well as workable backlog) can be performed.\(^71\)

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\(^69\) The worker has little or no possibility for absorbing self-induced variability, e.g. through catching up with a delay inflicted by a moment of underperformance. If at any point failing to meet the tact time criteria, the worker risks stopping the production line and a visual control system will make it clear to all who inflicted the interruption. The critique of these practices emerged already before the term lean production entered the broader production management debate. For a discussion on JIT practices specifically, see e.g. (Wilkinson & Oliver 1989).

\(^70\) See the introduction of the term ‘lean’ as opposed to ‘buffered’ production - as coined by Krafcik (1988), discussed in the beginning of this chapter – and the alternative terminology ‘fragile’ vs. ‘robust’ production. A lean production process will be fragile (vulnerable), where process ‘robustness’ achieved through buffering will not be ‘lean’.

\(^71\) The question of reducing volume output variability vs. the approach of reducing workflow reliability, so it appears, may sometimes cause confusion in debate on lean construction. The next example of critical debate – questions of point of focus in lean construction – involves aspects relating to this distinction.
The discussion on HR implications of lean construction techniques is naturally very important, and more empirical research documenting stress-reaction and other negative HR impact following different (lean) construction management approaches would make important contributions to the continuation of this discussion. At present the author knows of no examples where the implementation of lean construction has been connected to the removal or limitation of the rights of workers and unions, as have been a criticised feature of Japanese lean production (Berggren 1990; 1993b; Dohse et al. 1995; Jürgens 1995; Williams et al. 1995). Similarly the high degree of job security - promoted in dominant lean literature (Ohno 1988; Shingo 1988; Womack et al. 1990) as essential to successful implementation of lean practices - has not been addressed in the lean construction debate.

Research into possibilities for construction to benefit from lean approaches while avoiding negative HR impacts, as called for by Howell & Ballard (1999), is still largely unaddressed.

3.5.2.2. Questions regarding point of focus in lean construction – critique by Thomas et al.

An important discussion has followed the publication of a large report by Thomas, Hormann, de Souza & Zavrski for the CIB (CIB 2002). In the report and in two articles (based on empirical studies) it is argued that production throughput variability should be reduced to ‘acceptable levels’ and the remaining variability absorbed by flexible workforce management strategies. Flexible workforce strategies are found to be a more performance efficient alternative to reducing the variability of workflow which, the articles suggest, has been overemphasised in lean construction (Thomas et al. 2002; 2003). It is concluded that lean construction should focus more on labour flow and workforce management strategies to achieve better labour performance (Thomas et al. 2003).

The arguments and conclusions have been disputed by Ballard, Howell, Koskela and Tommelein in (Howell et al. 2004) and in (Ballard et al. 2005), and the critique subsequently rejected in (Thomas et al. 2004) and (Thomas et al. 2005).

The entire discussion, which involves a large number of aspects, shall not be repeated here. However, for this thesis two observations from this discussion are relevant. One is that the pleadings of debate following the two articles are marked by lengthy clarifications and obvious disagreement regarding what is meant by terms and definitions through which arguments are presented. Most important is the differences in perceptions and assumptions regarding the notion of ‘variability’ which was highlighted in the contributions by Howell et al. (2004) and Ballard et al. (2005): contrary to prevailing approaches to lean construction, the analysis, arguments and conclusions by Thomas et al. build on the assumption that reliable work flow means the same load placed on the production system from one time period to the next. This is set against the approach argued by the four lean construction proponents who define work flow reliability as the extent to which the production plan accurately match the tasks and assignments that are in fact being executed (in other words: plan conformance). One issue confusing the debate may be the different implications that e.g. workflow levelling has in project-based (lean) construction when compared to repetitive (lean) manufacturing.

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73 For a typical (repetitive manufacturing) production line operating with JIT and single-piece flow, constant workflow will also imply constant volume throughput. This is not necessarily the case in
The second observation is that the very perception of labour resource is an issue of fundamental importance to discussions on the application of lean techniques, methods and approaches to construction management. If understanding production processes as involving a set of different flows\textsuperscript{74} it follows from simple HR considerations that the flow of labour cannot be considered a simple production parameter like the flows of e.g. materials. This aspect is brought up by Ballard \textit{et al}. (2005) emphasising that labour is not a commodity and should not be treated as such by research. From this concern the authors argue that they do not find that the recommendation of applying flexible workforce capacity strategies – as were suggested by Thomas \textit{et al}. (2003) - are ethically justifiable.

It can be concluded that the discussion has raised important issues regarding potential consequences for health/safety and work/employment conditions affiliated with different lean approaches. This aspect is very interesting since similar HR issues have given rise to heavy criticism in the far more intense debate there has been on lean production, and which Green (2002) has found to been neglected in discussions of lean construction (see above).\textsuperscript{75}

**3.5.2.3. Economics- or production-based theories as the basis for theory development for construction project management? – critique by Winch**

The question about an appropriate fundamental approach for the development of a production management theory has been addressed in a number of publications of which Lauri Koskela appears to be the main contributor (Koskela 2000; 2003; Koskela \textit{et al}. 2004; Koskela & Ballard 2006). Economics-based approaches to managing projects through decomposition of elements, cost and transactions are criticised for offering an inappropriate basis for theory development since they do not address directly the transformation, flow and value perspectives of production that Koskela (2000) argued to be central for understanding the production phenomenon. It is argued that a theory of project management should instead be based primarily on theories of production.

Responding to a call from Koskela \textit{et al}. (2004) and Koskela & Ballard (2006) to engage in a discussion on these issues Winch (2005; 2006) argues that on its own a production-based management approach will be insufficient since it does not address vital contextual issues of transaction costs, market functions and intra- and inter-organisational business processes of the supply chain. While acknowledging that the work on lean construction has contributed to the understanding of the project management field Winch (2006) concludes that the proposed dichotomy between theories of economics and theories of production is not meaningful.

The many facets of the discussion cannot be summarised here, but an important observation is that implicitly Winch argues from a perception of lean construction narrowly understood as building on a theoretical element constituted by the TFV construction where such simple correlation between volume throughput, workflow and labour productivity rarely exists.

\textsuperscript{74} As according to e.g. the TFV theory (Koskela 2000) on which much of the discussion builds.

\textsuperscript{75} Within the International Group for Lean Construction a few conference papers have discussed health and safety issues in relation to aspects of lean construction. Interestingly a contribution from a Danish contractor has reported a remarkably improved safety record as the most significant outcome of its implementation of the Last Planner System (Thomassen \textit{et al}. 2003). This had come as a surprise to the contractor who explained this benefit as an outcome of the increased focus on production processes and on-site coordination.
model (Koskela 2000) and practical application through the framework of the Lean Project Delivery System (Ballard et al. 2002). In the perspective of the lean construction debate at large such limitation is arguably regrettable.

3.5.2.4. Oversimplified perception of value

Over some years ‘value’ has gained increasing popularity in management theory and practice, in economic theory and in a large number of construction sub-disciplines as e.g. architectural management. Value as a concept, however, has many different meanings and usages, which in relation to building and construction has been discussed by e.g. Best & de Valence (1999), Jensen (2005) and Wandahl (2005). Jensen (2005) highlights the basic difference between ‘value’ in the singular and ‘values’ in plural. Where ‘value’ expresses the worth of something, ‘values’ relate to a range of dimensions of which some are personal beliefs and social behaviour. Jensen identifies six categories of value:

1. Religious values: values as belief system
2. Behavioural values: value as moral and ethics
3. Economic value: value as exchange
4. Use value: value as utility
5. Cultural value: value as meaning and sign
6. Perception value: value as experience

Manufacturing and construction are typically connected to several, and sometimes all, of these six different types of value(s). With its many stakeholders, long durability and geographical immobility this is not least present in construction. However, the lean philosophy and common lean techniques approach mainly value from the perspective of economical value and use value. In relation to publications on lean construction this issue has been briefly discussed by Wandahl who illustrates his findings with a few examples (Wandahl 2005 pp. 60-61, 63).

Winch (2006) has argued that lean construction builds on a unitary concept of value deriving from quality management, which he concludes is inadequate for developing methods for ensuring that incentives are aligned both within the project coalition of interests and between the project coalition and external interests. Broader perceptions of value, values and value concepts do however seem to gather more and more attention within publications on lean construction and recent publications from the International Group for Lean Constructions have addressed the need for more multi-facetted approaches to value(s). Examples are: (Garnett 1999), (Emmitt et al. 2004; 2005) and (Wandahl & Bejder 2003).

3.5.2.5. Concluding comments on the critical debate on lean construction

The debate on lean construction is developing and the emergence of critical debate in leading academic journals may possibly reflect that lean construction as a field is maturing in terms of methods, understanding and debate. An important observation from the debate is that terms and definitions appear to be a pivotal point of the discussions. Some confusion reigns regarding the perception of what is meant and implied by ‘lean construction’ and also regarding what lean construction is not (or should not be). However, also aspects regarding the use of technical notions of e.g. ‘workflow’ and ‘value-adding activities’ appear to be subject to some confusion. Evidently this provides some difficulty in getting a grip on the actual (critical) discussion agenda which is yet to develop its points of focus.
3.6. Working definition for ‘lean design’ and ‘construction’

The literature review of this chapter shows that there is a) no common definition of ‘lean design’ or ‘lean construction’, and b) no definitions are so widely adopted that their prevalence would per se suggest their application for this thesis. Given this situation and the broad variety of conceptions rampant in the lean construction debate, it can be argued that the choice of working definitions is widely a question about whether to opt for narrow or broad definitions. The choice is by no means obvious and there are good arguments for and against both options:

Choice of a narrow definition: In favour is the fact that the debate on lean/design construction is highly fragmented and that the development of more focused discussion may be impeded by broad, vague and interpretable conceptions of ‘lean’, ‘lean design’ and ‘lean construction’ and diverse interpretations of concepts/notions/terms applied in publications on lean issues.76 Against the choice of a narrow definition speaks the risk of achieving an insufficiently limited overlap with the large majority of lean design/construction publications so that this thesis in fact positions itself outside the debate for which it is meant to contribute.

Choice of a broad definition: In favour speaks the interest in positioning this research within the lean design/construction debate as well as within the broader construction management debate. Against the adoption of a broad definition speaks that this limits the extent to which a clear and narrow focus can be maintained in the discussion of the research questions.

From a relative weighting of these considerations it was decided to opt for a broad working definition as the basis for this research. In short, it was decided to position this thesis within the broader lean construction and construction management debate. As previously discussed, ‘lean’ in design and construction is still developing and it is at present difficult to forecast if/where debate may focus in the future. While it is obvious that there is a need for a better common understanding of the terminology used, no position has been taken regarding whether or not there is an actual need for the lean design/construction debate to be based on a more narrow definition. Instead it is the hope that the literature review of this chapter can contribute to future work of developing further the theme of lean application to the construction context, and that it can be useful for establishing a better common understanding.

The working definition chosen builds on the most basic elements of the lean philosophy that seem to be the most common features that can be extracted from the literature review on lean production/manufacturing. As mentioned in the beginning of this chapter these elements are:

76 See this chapter’s discussion of the critical debate on lean construction. At several levels the debate appears to be confused by diverse interpretations of ideas and concepts discussed. This is perhaps most clearly illustrated in the exchange of views between on the one side Thomas et al. (2002; 2003; 2004; 2005) and on the other Howell et al. (2004) Ballard et al. (2005). This example highlights how the absence of a generally shared/accepted system of terminology can be a serious obstacle for focussed debate to emerge in the broader construction research society.
A focus on eliminating/reducing waste and sources of waste in relation to the delivery of artefacts or services as of value to the (end) customer.

End customer preference is adopted as the reference for determining what is to be considered value and what is waste.

Management of production and supply chain from a (customer) demand pull approach.

Approaching production management through focus on processes and flows of processes.

An (at least to some degree) application of a system’s perspective for approaching issues of waste elimination/reduction.

Within the construction debate on application of ideas from the lean philosophy the TFV (transformation/flow/value) understanding of production/construction (Koskela 2000) is widely adopted and of particular interest because it - with its overall approach to the phenomena of production - positions itself within the broader debate on production and production management beyond the limits of the construction domain. The TFV understanding will therefore be adopted for this thesis’ working definition of lean design/construction.

3.6.1. Choice of working definition

On the basis of findings and considerations discussed above, this thesis adopts the following working definition of ‘lean design’ and ‘lean construction’:

**Lean design and lean construction:**

I. Applies a systems’ perspective to enhance value and eliminate/reduce waste and drivers of waste in the construction project;

II. Adopts customer (client/user/stakeholder) preference as the reference for determining what is to be considered value;

III. Approaches design and construction management through a focus on processes and flows of processes;

IV. Adopts an understanding of design and construction/production activities from a perspective of three simultaneous conceptualisations: 1) transformation; 2) flow; and 3) value-generation;

V. Manages design and construction/production processes with a (customer) demand-pull approach as far as this is applicable.

A few comments on this working definition should be made. The literature on the lean philosophy, lean construction and lean design did not suggest that two (principally) different definitions for lean design and lean construction would be appropriate for this research. With a focus on enhancing (customer) value and eliminating/reducing waste from a system’s perspective, the lean philosophy and its basic elements (I-V as listed above) address both design and production processes. However, the practical implications of applying a lean approach are naturally very different in the case of construction design than when compared to construction production/assembly.
3.7. Design/construction integration – choice of approach

As discussed in the introduction (Chapter 1), design/construction integration is a very large and broad theme that has been explored from a variety of perspectives and approaches. So far there has been set no actual research agenda for investigating the theme of design/construction integration in relation to the application of the lean philosophy.

If considering the lean philosophy’s focus on value optimisation and waste minimisation, the ‘lean role model’ of the Toyota Production System and the applied measures of addressing waste through systematically pursuing resource efficient flows of information, materials and transformations, it can be argued that four different integration approaches of the larger construction management debate would, each in their own way, be obvious choices:

- Aspects of vertical and/or horizontal integration in the construction supply chain and in between construction delivery and the management of real estate facilities and related services.\(^77\)
- Integration of information systems for product and processes (often approached through a strong IT orientation), e.g. through specific models.\(^78\)
- Integration of working practices and collaborative processes in the construction project organisation.\(^79\)
- Constructability (often dealt with from the perspective of specific practical advices for producing designs with a high level of constructability, e.g. the ‘design for assembly’ approach).\(^80\)

Many perspectives on integration would arguably be of high relevance to this thesis but due to the limitations of the doctoral research, working practices and collaborative processes (third bullet point) will provide the main perspective adopted for this work. However, as illustrated by the three case studies, practical pursuit of design/construction integration is influenced by a large number of contextual factors why it is not possible to completely leave other perspectives out of consideration.

As mentioned in the Introduction (Chapter 1) Baiden et al. (2006), based on a comprehensive literature review, have suggested that integration can be considered as “the merging of different disciplines or organisations with different goals, needs and cultures into a cohesive and mutually supporting unit”, and that integration in construction describes the introduction of “working practices, methods and behaviours that create a culture of efficient and effective collaboration by individuals and organisations”.

Baiden et al. (2006) use the term ‘integrated construction project team’ to characterise “a highly effective and efficient collaborative team responsible for the design and construction of a project.” Integration here refers to the team bringing together “various skills and knowledge, and removes the traditional barriers between those with responsibility for design and construction in a way which improves the

\(^{77}\) Some examples of publications are: (Bröchner 1990; 2003); (Haugen 2000).

\(^{78}\) Some examples of publications are: (Anumba et al. 2000); (Austin et al. 2000; 2002); (Bouchlaghem et al. 2004); (Kimmance et al. 2004).

\(^{79}\) Some examples of publications are: (Nam & Tatum 1992); (Austin et al. 2001; 2002); (Baiden et al. 2006).

\(^{80}\) Some examples of publications are: (Adams 1989); (Ferguson 1989); (Griffith & Sidwell 1995); (Austin et al. 2001); (Holroyd 2003).
Towards an understanding of ‘lean’

BYG Bo Jørgensen (2006) 109

Effective and efficient delivery of the project” (p. 14). The authors thus approach the theme of design/construction integration and team integration from the perspective of achieving integrative project processes and working practices. This feature is shared by lean design/construction that also primarily focuses on processes.

Based on a comprehensive review of publications on design/construction integration, Baiden et al. identified a number of characteristics – all linking back to project processes - for integrated ways of working in construction. On the basis of these findings it was proposed that:

“The delivery team in a construction project can be described as ‘fully integrated’ when it:

- has a single focus and objectives for the project;
- operates without boundaries among the various organization members;
- works towards mutually beneficial outcomes by ensuring that all the members support each other and achievements are shared throughout the team;
- is able to predict more accurately, time and cost estimates by fully utilising the collective skills and expertise of all parties;
- shares information freely among its members such that access is not restricted to specific professions and organisational units within the team;
- has a flexible member composition and therefore able to respond to change over the duration of the project;
- has a new identity and is co-located, usually in a given common space;
- offers its members equal opportunities to contribute to the delivery process;
- operates in an atmosphere where relationships are equitable and members are respected; and
- has a ‘no blame’ culture.” (p. 14-15)

In addition to the literature review Baiden et al. (2006) studied nine successful construction projects that had been managed by award winning construction managers. Of the project teams studied none were found to be completely fragmented, and not a single one could be categorised as ‘fully integrated’ according to the complete range of criteria listed above. In none of the cases were the project team members able to operate seamlessly as a single team.81 The authors conclude that this infers either that ‘fully integrated teams’ are not necessary for effective team operations, or that the construction sector must overcome significant organisational

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81 The authors summarise the findings from the project teams surveyed in six points (p. 20).

"Project teams:
- were flexible and possessed the necessary dynamics for the successful executions of the projects;
- did not operate seamlessly and members continued to work disjointedly within their individual organisations;
- were not able to form a new single team that was co-located;
- had equitable relationships and ‘no blame’ cultures and thus tended to work towards joint resolution of problems;
- formed good relationships at the early stages of the project, which led to high levels of trust and removal of adversarial attitudes; and
- created a project culture where all participants worked towards a common project goal.”
and behavioural barriers if the benefits of integration are to be fully realised in the future (p. 22).
Leaving aside that such questions regarding practical achievement of ‘full integration’ of project teams still remain to be answered, an important conclusion that can be extracted from the research is that it is possible to pursue a significant degree of process integration across organisational boundaries.

3.7.1. Design/construction integration in a lean perspective

Principally the lean philosophy promotes an integrated approach to designing and making (discussed above) and some lean construction proponents have proposed that ‘production’ should be understood as consisting of both designing and making (e.g.: Koskela 2000; Ballard & Zabelle 2000; Ballard 2002)\(^{82}\) but, all in all, a review of publications on lean construction suggests that terms are used in a large variety of ways and different notions of ‘design’ and ‘production’ appear to co-exist. For clarity, this thesis will apply the ‘traditional’ terminology and use the term ‘production’ for the processes concerned with the physical making of what is previously specified through design.\(^{83}\)

While it is important to be aware of differences in the terminology used, the need exists for specifying on a more concrete level what is understood by a lean approach to design/construction integration.

3.7.1.1. Working definition of integration of lean design and lean construction

It can be argued that ‘lean design’ & ‘lean construction’ both represent integrative approaches. For this thesis integration of lean design and lean construction will be understood from the perspective of achieving that a design/construction project team works integrally in pursuit of a lean approach to project delivery.

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\(^{82}\) As explicitly formulated by Ballard: “Within the lean construction movement, production is conceived as the integrated designing and making of things. ‘Making’ has the job of conforming to requirements. Design produces those requirements.” (2002, p. 288).

\(^{83}\) Though the present author is sympathetic to the notion of perceiving production as consisting of both designing and making, a ‘conservative’ terminology has been adopted from the belief that the furthest possible conformance with the terminology of the main construction management discourse may significantly enhance communication of the present research.
Chapter 4

Case I
4. Case I: Housing project in Denmark

This case examines the progress of the early design phases of a Danish house-building project. The project was observed through the second half of 2003 from the commencement of the design committee’s work. However, the project was postponed and discontinued during the research.

The project was a design-build project, led by a large Danish contractor for a client (a large institutional investor) wanting to procure 100 apartments (for rental). The project was unique in the sense that it a) was intended to be the first of a series of five housing projects carried out in cooperation by the same team (consisting of design-built contractor, architect and engineering consultants) for the same client, and; b) that a development strategy had been formulated in order to systematically improve performance throughout the period of cooperation and to provide experience for the improvement of performance on future project engagements. The original intention was to study a few of the five projects, but this plan had to be revised following the project postponements. – For the case study methodology applied, see Chapter 2.

In spite of the project becoming indefinitely postponed, long before the detailed design was complete, the case illustrates some of the challenges associated with integrating design and construction at large building projects. The case illustrates how practical difficulties of involving the wider construction supply chain in lean initiatives may easily become a hindrance for achieving an integrative approach. Specifically the case highlights the importance of the position taken by the client and of the active involvement of client representation in design processes.

4.1. Case description - introduction

As mentioned above, the project was intended to be the first of a series of five housing projects requested by a large institutional investor. In total these five projects would have had a budget of 500 million DKK (€ 67.3 mill.) approximately equally divided over the five projects but with increasing performance improvement enabling a 15% price reduction per square meter from the first to the fifth project. When the first project was started up it was expected that all five projects were to be completed over a period of about four years.

The client’s decision to build these housing facilities was prompted by a recently approved publicly funded subsidiary programme, the so-called “Housing Package”84, intended to encourage private investors to build housing for rental and thus oblige the market demand for this type of homes. When the first of the five projects (the project here studied) entered the design and early scheduling stages, the client had already applied for support from the subsidy programme in the anticipation that this would be granted.

4.2. Case history

At the end of 2002 the client examined the Danish construction market and was in contact with potential contractors interested in bidding on a series of the five projects that were to be executed under a design-build contract framework. The client’s intentions were that all five projects should be delivered by a permanent project team consisting of, in addition to the design-build contractor, architect and engineering consultant. The client had also requested that cooperation should take place within a

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84 ‘Boligpakken’ as the programme was named in Danish.
partnering framework intended to enhance client value and project participant satisfaction. For the benefit of all parts, continuity between the five projects was expected to gradually increase performance through experience-based team learning and development activities.

4.2.1. The tender process
In January 2003 the client invited three large contractors on the Danish construction market to bid for tenders. Through a process of a ‘best value’ competitive tendering the client wanted to select for the project a design-built contractor with a strong delivery team (it had been made an explicit demand that bidding contractors should specify their team of architects and consultants, including the key staff of the project organisation) that under a design-build framework and with the use of partnering principles could take part in developing the five projects and deliver them with gradually increasing performance. For the tendering process the projects were not defined in any great detail except in terms of volume, a few demands regarding architectural and technical quality, and the budget frame. The selection criteria were:

- **Project organisation** – organisational structure, participants, previous experience, proactive involvement of subcontractors, and suggestions for how to form a well functioning project group with common goals.
- **‘Ethics agreement’** – commitment to comply with a number of ethical rules of sincere communication, punctuality, fulfilment of agreements etc.
- **Previous experience** from similar projects.
- **Process description** – bidder’s detailed proposal for execution of planning, development, design and overall project delivery.
- **Transparent project economy.**
- **Economic framework** – commitment to comply with the economic framework as defined in the tender. This included a 15% reduction in construction costs from the first to the last of the five projects.
- **Ideas for delivering the first project of the five.**
- **Quality level** – examples of previous projects delivered in a quality similar to those now tendered, and a description of the architect’s ideas for projects with a high level of repetition.
- **Quality management and environmental management.**
- **Performance measurement** - bidder’s proposals and/or documented experiences with performance measurement.
- **Management of experience and organisational learning** – bidder’s knowledge of management systems and documented experience of managing e.g. feedback from client and suppliers.
- **Dispute resolution** – bidder’s proposal for a forum for resolving disputes, should such occur.
- **Specific site for the first project of the five.**

(Source: invitation to tender document, January 2003)

The client chose a design-built contractor (from here onwards referred to as the DB-contractor) who had established a partnership with a major engineering consultant firm and a large architectural design studio, both of which had considerable experience with designing large housing projects.
An important detail to note is that the tender and the project contract did not bind the client to complete all five projects. Contracts were executed one at the time and under the precondition that the market and the client’s business developed according to expectations.

4.2.2. About the project parties
The DB-contractor and the two design partners are all established and well known within the Danish construction sector, whereas the client plays a less prominent role among institutional investors:

- **The DB-contractor** is among the largest contractors in Denmark. Already at the time of the case study the company had several years of experience in working with process-orientated production systems and was among the first contractors to adopt tools and procedures of lean construction for large projects in Denmark. In addition to project management and control tasks, the company’s in-house department for structural engineering was to provide the structural design and was therefore represented in the design committee.

- **The architectural design firm** is one of the largest architectural design companies in Denmark. The company is involved in all types of projects and is very experienced with the building of housing facilities.

- **The engineering consultant** is among the largest engineering consulting agencies in Denmark. The company offers a wide range of design and consultancy services within all technical disciplines of construction. At this project the engineering consultant was to provide the designs of the various installations (electrical, HVAC, water, sanitary facilities etc.) for the building.

- **The client organisation** was not experienced with the client-role on large projects. However, from previous employment the client’s project manager had many years of experience from the management of a large contracting organisation.

4.2.3. Background
In the 1990s the three partners (DB-contractor, architect and engineering consultant) had cooperated on a business development project, the so-called ‘PPU Project’, within the framework of a year-long publicly supported construction sector development programme, the ‘PPB Programme’. The three partners believed that this experience had contributed substantially to the client’s choice of their team for the five projects.

4.3. The project organisation
The project studied was organised around a steering committee consisting of four persons, representing the client, the DB-contractor, the architect, and the engineering consultant. This steering committee was intended for dealing with overall decisions.

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85 The PPB Programme has been studied and reported by Clausen (2002).
for the project while ensuring continuity and compliance with the objectives, both for the projects individually as well as for the project series at large.\textsuperscript{86}

During the spring and summer of 2003 the DB-contractor went through a process of organisational restructuring and adjustments during which the company’s representative in the project steering committee left. His place was taken over by the head of the newly formed production system department.

In the steering committee representatives were high-ranking managers. For the design committee the DB-contractor and its two partners chose very experienced people for all key positions. The design manager (representing the DB-contractor) already knew the engineering consultant’s two representatives in the design committee (except from a new electrical system designer who joined the project as a replacement in late August 2003) but the architectural studio’s two representatives were new to him. He did however know that the architectural studio’s project manager, the chief architect for this project, had personal experience from the PPU project. According to the design manager this architect was well known in the DB-contractor’s organisation where he carried a reputation for doing competent work and possessing good cooperation skills.\textsuperscript{87}

The design manager expressed to the researcher his satisfaction regarding the fact that the design committee had been composed from individuals who he considered all to possess the right professional qualifications while also being able to contribute with the right attitude to the process of collectively contributing to the successful execution of the project throughout its different phases. According to the design manager his superior (the head of the DB-contractor’s section for housing projects) had described the people allocated to the project as “the first chain”, using a metaphor from ice-hockey to illustrate that the job was given top priority and assigned the best human resources available. Within the design committee and the DB-contractor’s organisation it was openly discussed that this, and the subsequent four projects, were ‘high profile jobs’ for which the company managements had great expectations of successful completion.

4.3.1. Design committee’s strengthened role

From the very beginning the client and the three project partners decided to cooperate in what they considered to be an untraditional way, reducing the amount of tasks

\textsuperscript{86} It is relatively common for projects in Denmark to have a steering committee as the formally highest decision-making body. The project management executes the project in accordance with the guidelines provided by the steering committee. The client (sometimes represented by an external project consultant) usually composes and chairs the steering committee. The committee’s purpose is to enhance project cooperation and create win-win situations that support the overall project objectives of the client. The committee can be considered a sort of ‘integrator’ between key stakeholders of the project and is intended to secure the project’s development in accordance with the intentions and interests of the client and the project team. The steering committee can also be seen as an integrator between the project and the individual company organisation.

There is no fixed model for the composition of steering committees but it is common that at least the client, architect, contractor (and sometimes also engineering consultants) are represented. Usually representatives are at top management level of the organisations they represent. At some large projects also other interests e.g. of neighbours, public authorities (and possibly also other external stakeholders) are represented in the steering committee. It is however more common that these take seat in a separate ‘monitoring committee’ that is to enhance the communication between project management and external stakeholders that will, in one way or another, be influenced by the construction project. The steering committees of Danish construction projects are in most respects similar to steering committees of consortia or joint-ventures as are known from other industries.

\textsuperscript{87} Interview with the design manager, September 22\textsuperscript{nd} 2003.
usually dealt with at steering committee level and instead assigning the design committee (where the client would, however, have no seat) more control over decision-making processes. Overall objectives were still to be decided upon in the steering committee but discussions on detailed project design were to be left exclusively to the design committee and conducted on the basis of the overall decisions carried by the steering committee. The aim of this division of responsibility was to leave as many design decisions as possible to the forum that had the strongest design and construction process competence. It was hoped that this would lead to more thoroughly integrated design and construction processes for the benefit of all stakeholders.

Through the enabling of a faster decision-making process during detailed design it was also expected that overall project objectives could be more effectively met in comparison to longer and more rigid bureaucratic procedures that, so it was believed, often hampered value delivery. This did not mean that the client should be kept in the dark regarding matters of design development, and the steering committee was to be kept well informed about the work of the architects and the design committee. As will be discussed later in this chapter, it soon became clear that there were, however, different interpretations about this division of tasks and about the procedures for progressing with design decisions.

4.4. Project delivery strategy

At a very early stage the project partners and the client identified a strategy through which they expected to benefit from the continuity between the five projects. The strategy, which was to contribute to meeting the cost reduction target from the first to the last project, consisted of the following elements:

- **Standard housing units**
- **Development themes**
- **Lean design and lean construction**
- **Partnering**
- **Proactive involvement of subcontractors**

Continuous team-learning throughout the five projects was expected to support the DB-contractor and its project team in all these development activities (discussed later in more detail).

4.4.1. Standard housing units

The client and the project partners agreed to develop a design concept based on five to six standard designs for housing units (flats/apartments) that were to be applied for all five projects. This would bring forth several advantages: much detailed design could be reused, later projects would benefit from experiences already gained, and a high reiteration factor was expected to enhance productivity rates.

The parties expected that the concept of standard apartments for all projects would greatly support an industrialised production process and enable the DB-contractor to negotiate favourable prices and cooperation terms with suppliers and manufacturers. With the high volume of the five projects it was expected that some suppliers would be interested in contributing to product and process development activities. The aim was to actively involve suppliers already during the early project phases in order to

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88 Project design kick-off workshop, August 20th 2003; interview with the design manager, Sept. 22nd 2003.
strengthen cooperation and an overall process-orientated approach throughout the project(s). It was believed that the designs would benefit from the expertise of suppliers and thus result in solutions of higher client value and improved constructability.

4.4.2. Development themes

Already during the process of preparing to bid for tenders on the projects, the DB-contractor and its team of architect and engineering consultant decided to exploit a possibility for systematically work with some development themes for the five projects. As subjects for development themes the design committee chose issues that were considered to frequently have a significant impact on value delivery and project performance by causing special problems for construction processes, use and renovation, as well as for future modifications. These development themes were:

- Bathroom cabins
- Balconies (for the first project – studied in this case)
- Facades
- Installation shafts
- Prefabricated elements

Through investing extra effort in the above themes when designing the first building it was expected that client value delivery would be enhanced through technically better solutions and improved quality while the DB-contractor and its team of consultants would benefit from reusable designs and more efficient production processes. The partners expected that the combination of a small number of standard apartments and a strong focus on the development themes would gradually improve the building process efficiency over the five projects. This was a key element in the strategy for reducing costs with 15%.

In addition to value delivery, productivity and profitability on the five projects the contractor and its partners expected to develop knowledge, experience and competences that would be directly applicable to future projects.

4.4.3. Lean design and lean construction

Lean design and lean construction concepts were to be applied to all five projects for the benefit of planning, scheduling and the reduction of non-value-adding activities. Over a few years the DB-contractor had developed its own concepts for lean design and lean construction. During a period of about two to three years the DB-contractor had developed, implemented, and gradually sophisticated the company’s site-orientated lean construction concept that was applied to large projects. The backbone of this concept was The Last Planner System of Production Control (Ballard 1994; 2000a), a tool that the company had combined with an educational strategy aimed at teaching the Last Planner System’s method while promoting an understanding of (construction) production as perceivable from a TFV (transformation, flow, and value) perspective as according to (Koskela 2000).

In addition to the Last Planner System the lean construction concept included extensive use of process facilitation. On large projects the DB-contractor operated with a so-called process facilitator who, in a non-formal way, was to support planning, coordination and cooperation during the planning and execution of site activities. One of the main responsibilities of a process facilitator was to ensure active involvement and commitment from the different key-persons involved in the project.
It was a basic philosophy behind the concept that a project’s financial matters were to be kept strictly separate from the facilitator’s area of responsibility. Recognising that cooperation often suffers problems that derive from conflicts between the parties involved, all such responsibilities were assigned the project manager. The underlying idea behind this division was to enable the facilitator to concentrate on project processes, and avoid that matters of basic coordination and cooperation would become compromised due to conflicts or disputes over financial matters.89

While the site-orientated lean construction concept had gradually become established as usual business practice in the DB-contractor’s organisation, the lean design concept was a recent initiative that had been pilot-tested on a few medium-sized projects. However, it was yet to be matured.90 This initiative was based on the same principles (reactive activity planning/scheduling and process facilitation) as the lean construction concept but had not yet been thoroughly applied in large scale.

In the project studied the design manager was experienced with both the lean design and the lean construction concepts. The DB-contractor organisation’s coordinator of lean activities expected that the five projects would provide valuable insight into an integrated lean approach to construction procurement.91

For further introduction to the Danish perception of and approach to lean construction, see (Jørgensen et al. 2005).

4.4.4. Partnering - transparent project economy

Within a partnering framework some basic cooperation policies had been adopted. The most important of these was the policy of ‘open/translucent project economy’: throughout the project’s duration the four partners (client, DB-contractor, architect, and engineering consultant) were to grant each other full access to information about income and expenses on all the five projects as well as of related activities. This was decided in order to enhance that decision-making could take place in respect to the position of all parties, which was to strengthen trust and collaboration and prevent sub-optimisation.92

In the tendering documents that specified the client’s demands it was emphasised that bidders should commit to manage and resolve conflicts on their own and, to the furthest possible extent, avoid involving the judicial system. In other words: the client expected the project participants to cooperate according to the objectives of the project and in the partnering spirit. During the project design kick-off workshop this was openly discussed and the design committee members explicitly expressed that, partnering agreement or not, this was anyway an unwritten rule for operating and surviving in the Danish construction business. The ‘informality’ of the construction business in this regard was by some participants described through comparative anecdotes deriving from their experiences gained when working abroad or on projects that involved non-Danish companies. Traditions and common practices of formality and informality in the Danish construction industry lies beyond the scope of

89 For a discussion of process facilitation and the role of the process facilitator in this contractor’s lean construction concept, see (Jørgensen et al. 2004b; 2004c).
90 One of these projects had been subject to an external evaluation (By og BYG 2004) requested by the DB-contractor.
91 Conversations with the lean activities coordinator, August 2003.
92 Interview with the design manager, Sept. 22nd 2003. (This research did not have access to all information about the partnering agreement).
this thesis but is an issue of some importance because also the ‘lean’ concept, as described above, was largely based on the application of informal process management (described by Jørgensen et al. (2004b; 2004c)).

4.4.5. Proactive involvement of sub-contractors in the design process
From the very beginning of the project the intention was to involve selected sub-contractors in decisions regarding some basic matters concerning structural principles, assembly methods etc. Through an early selection of central subcontractors the design process was expected to benefit from the suppliers’ expertise which the DB-contractor hoped would stimulate constructability and enhance shared understanding of the project objectives.

Through collaborative design the DB-contractor expected to achieve more integrated design and production processes, be able to manage design processes with fewer late-stage changes, to develop design solutions securing subcontractors efficient assembly processes etc., and thus improve the scope for efficient project management.

At an early stage (spring/summer 2003) of the project, potential sub-contractors for the most critical jobs were contacted and some of these were subsequently selected. This selection was made by high-ranking managers of the DB-contractor together with members of the steering committee. This took place in cooperation with an internal consultant of the DB-contractor whose head of production systems, together with the head of the division for house-building, carried the final decision on the selection of sub-contractors. Neither the design manager nor the process facilitator took part in selecting the sub-contractors, and they were consulted.

4.5. Progress of the project: design start up and discontinuation
The first steering committee project workshop was held in the spring 2003 when the briefing process was being finalised and the conceptual design phases begun. The design committee started its work in August 2003, anticipating that the excavation works on site could start early April 2004.

4.5.1. Project postponements
Already in the autumn 2003 further design work was postponed. As mentioned earlier, the client expected to receive public support through a subsidy programme. However, the application process took longer than expected so the project had already entered conceptual and early detail design phases without the client having received any guarantee for governmental subsidies. In the early autumn the client and steering committee decided that further detailed design work should not be accomplished before verified information regarding the subsidiary support was available. This was expected to happen in only a few weeks. Meanwhile the architects and the client should continue to work out new or adjusted proposals for apartment designs and house facades in order to finally reach design solutions that could reassure the client to continue with these designs for all five projects.

Several times project resumption was postponed. In February 2004 the client’s application for subsidiaries through the Housing Package was rejected. The project was at that point postponed indefinitely. In January 2005, almost one year later, the client and the DB-contractor decided to continue with the project. Within the limits of
the current research it was then no longer possible to study the project during its continuation.

4.6. Findings: Outcome of the project delivery strategy

4.6.1. Standard housing units

The expected benefits of operating with a series of standard apartment designs were linked to the execution of subsequent projects. None of these are covered in this case study which thus cannot provide any insight into the feasibility of this important element of the project delivery strategy. It was, however, observed, that the progress of design was troubled by what the members of the design committee perceived as uncertainty regarding the stability of client decisions (see the bullet point ‘Facades’ under ‘Development Themes’, below).

4.6.2. Development themes

- **Bathroom cabins:** As the project started, the design committee appeared to have high expectations in the development of a good prefabricated bathroom cabin solution that would provide the owner and users with a good product while enabling a fast and efficient assembly process. With five continuous projects and a total volume of 500 apartment units the DB-contractor expected to be able to commit a supplier into the development of a good solution that would both contribute to meeting the above criteria and enable the DB-contractor to purchase the cabins at a favourable price. The DB-contractor and its two project partners surveyed the market for cabin manufacturers and visited a couple of these to obtain more information about their products and hear about the manufacturers’ ideas for further developments.

Eventually one supplier was identified as the most obvious choice for further cooperation. This supplier produced fully prefabricated bathroom cabins for ships and possessed a lot of experience and competence in designing and producing cabins that enables an efficient installation process. The company was a large-scale producer why the DB-contractor anticipated that it would be very interested in exploiting the opportunity for participating in developing products and competences that could potentially pave the way for new market opportunities in continuation of the finalisation of the five housing projects. In September the DB-contractor proposed to the bathroom cabin manufacturer that they should continue with a more thorough investigation on the possibilities for delivering to the project(s). However, the cabin manufacturer, much to the surprise of the contractor, declined the proposal. The reason given was that the cabin manufacturer had received an order of one thousand bathroom cabins for the US Navy and thus utilised its full capacity for delivering these. This came as a disappointment to the DB-contractor and the rest of the team who had identified this manufacturer as the preferred supplier. Several members of the design committee were relatively pessimistic regarding a fruitful collaborative development process with other manufacturers of bathroom cabins. The engineer responsible for mechanical installations found that the visits to the cabin manufacturers had been interesting but not encouraging. To the design committee he
expressed his view: “They [the cabin manufacturers] each have their product and if we want it we will have to comply with that product just the way it is. They appear to have no understanding of our wish to work with different processes of collaboration and new forms of cooperation.” The design manager and the chief architect appeared to share the scepticism but also understood the position of the cabin manufacturers. The architect formulated his analysis: “Like us they [the manufacturers] cannot be sure that there will eventually be a full 500 units and not just the first 100. I very well understand them when they are reluctant to engage in this [development activity]. (…) This rocks the entire statement of intent made by the client. If wanting to engage others in collaborative development there is a hell of a difference between announcing a frame of up to 500 units and to dare provide real committing promises.”

- **Balconies:** The partners expected that the investment of extra effort into designing good balcony solutions would pay off in respect to assembly processes on site, as well as in regard to client and user value. The design committee devoted much time and attention to the balconies, which was also in many respects critical for the further progress of design. The matter became rather complicated when the client expressed doubts about whether to eventually have balconies on this project or not. Architecturally the issue was considered to be very important for the entire architectural appearance of the entire building, while also strongly influencing the tenants’ perceived quality of the individual apartments. Other important aspect regarding value for the client and the users were the balconies’ influence on the energy performance and thermal comfort of the apartments and on the possibilities for carrying out future balcony renovations cheaply and with minimal inconvenience to tenants and neighbours. By designing concurrently both balcony and the production/assembly process the partners expected to achieve an appropriate assembly process where balconies (that are often seen as an issue complicating the production process) could provide better access for delivery of supplies, for storage etc.

Balconies were discussed at several design committee meetings. Mixed signals from client and steering committee made it difficult for the design committee to progress with its work. The architects found it difficult to satisfactorily continue developing the balcony design because there was doubt as to whether the client would stick to previous decisions and statements about the number of different apartment types and their designs. Furthermore, the application of tools, such as the LPS, from an early stage in the design development work was hampered because of uncertainties regarding the very basic decisions about the entire architectural concept. (See also ‘Facades’ below)

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93 Design committee meeting, September 17th 2003.
94 Balconies make, to some extent, thermal bridges which constitute an important design issue when building for the Danish climate and building codes.
4. Case I: Housing project in Denmark

- **Facades:** During the observation period when the project was studied, little of the design committee’s time was spent on working out detailed solutions for facades. Issues concerning facades shared most of the same difficulties as those of the balconies and the discussions regarding facades and balconies (see above) were highly interwoven. Missing certainty, mixed signals and lack of essential decisions from client and steering committee made progress slow. Along with proposals for standard apartments units (that had previously been presented to the client) the architects had developed a proposal for a façade design. It was the perception of the architects that the standard apartment units had already been approved by the client.

  When the detailed design was to be developed, under coordination by the design committee, the client representative expressed doubts about whether or not all the existing standard apartment designs were what the client organisation really wanted and if some of them should be modified or their number adjusted. At design committee meetings the architects expressed frustration over the situation, in particular over what they perceived as the client being under the misconception that the façade designs were something that could easily be readjusted whenever necessitated by changes to the apartment designs. However, in the perception of the architects, questions regarding facades were strongly interrelated with fundamental questions regarding apartment designs. Uncertainty regarding apartment designs thus had far-reaching consequences regarding the progress of vital parts of the overall design.

  Some extra time was eventually gained when the client started to reconsider the choice of location for the building and brought up the question of a potential change to another site in the same area. A shift of site could potentially be of some influence to the design of facades but the design committee agreed that the architects should first focus their attention on reaching a common understanding with the client organisation regarding the standard apartment designs.

- **Installation shafts:** During the observation period of this study questions regarding installation shafts were discussed only briefly. In the proposed standard designs the architects had included more than averagely spacious shafts with the aim to enhance buildability and access for maintenance. These shaft designs were discussed in the design committee where architects, contractor and engineering consultants soon agreed on the dimensions and on location that were found to be satisfactory to all parties. Discussions on how to secure an effective assembly process through the engineering design had just begun when the project was postponed and further work on technical details thus interrupted.

- **Prefabricated elements:** This issue was not as such discussed in very much detail during the case study period. Prefabricated elements for structural solutions and their connection to design of assembly processes

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95 Brought up by architects and design manager on design committee meetings, September 10th and 17th 2004.
were discussed in relation to the other development themes, but when the project became postponed an overall examination for optimising the element/assembly strategy had not yet taken place.

4.6.3. Application of lean design and lean construction

In the concept formulated by the DB-contractor the ‘lean design’ and ‘lean construction’ theme was approached through procedures of process facilitation and application of approaches from the Last Planner System (described above). During the observation period these procedures did not really come into much use but for carrying an introductory examination of tasks and responsibilities and for structuring these in relation to their preconditions. This was done in a workshop using cards representing tasks/assignments that were visually organised on a wall and shuffled around as the design committee discussed and identified what would be their right order. This hour-long exercise resulted in a sequential ordering of tasks, different from what all participants (including the design manager) had anticipated. The collaborative discussions revealed several issues where the designers had different expectations regarding preconditions for their fellow designers’ execution of individual assignments. After the exercise an evaluating discussion was organised with the contractor’s lean activities coordinator acting as facilitator. All participants expressed satisfaction and had positive expectations regarding the use of e.g. the Last Planner System in further work. - An interesting observation was that the participants, who all were experienced in planning and scheduling, became surprised about how many assignment cards they had to move further upstream in the process map when the exercise had revealed that these were themselves preconditions for other assignments. According to the lean activities coordinator this was what always happened when this workshop method was applied. It was his experience that planners always started with arranging the assignment cards too far to the left on the wall (the time line was left to right) and that this typically led to space problems during the exercise. His conclusion was that even very experienced construction professionals and project planners typically underestimate how many assignments that in fact serve as preconditions to others, and would thus eventually need to be moved back in sequence during such an exercise.

The design committee briefly discussed the possibilities for co-locating designers and design management in a shared drawing office during the most hectic periods of producing the detailed design when large numbers of construction documents would need to be produced in coordination with other designers. The idea originated from the top management of the three companies and a shared drawing office had been mentioned on the proposed organisation chart included in the tendering bid. The two architects in the design committee assured that they were ready to involve in a shared office if and when a final decision on this would be carried. However, they knew that their colleagues always “hate being located away from our own offices”. The chief architect had experienced that his colleagues and subordinates were displeased when spending longer periods away from their home design studio, partly because this complicated work on other projects in which they were involved, but also because they were away from the everyday life among colleagues. In this particular case the circumstance that the architects’ head office was in another part of the country than that of the DB-contractor and engineering consultant would have implied further complications to co-location.
4.6.4. Partnering and decision structure
The design manager believed that the formal partnering agreement itself was of a far minor importance than the very motivation behind establishing a team for executing a whole series of projects. However, it soon became clear that the progress of the design suffered and was impeded because of different perceptions of how design decisions were to be carried and by whom. At design committee meetings several participants, the chief architect in particular, expressed frustration about lack of certainty regarding the stability of previously carried decisions. This issue was discussed at several meetings and the design committee concluded that the division of work and responsibilities between the steering committee and the design committee did not function as according to the intentions:

- Separate from the design committee the steering committee had (so it appeared to the design committee that was not represented in the steering committee) spent much time discussing details while not carrying decisions regarding some of the overall objectives that would need to be specified before the design committee could progress with its work. The steering committee was perceived not to be working according to the announced intentions of strengthening the role of the design committee. Regarding project decisions and objectives several members of the design committee found that they received mixed signals from different representatives in the steering committee. The architects felt that even more different signals came from the client, as was their perception from the bilateral discussions between them and the client representative with whom they continually discussed the façade and apartment designs (see above).

During design committee meetings much time was spent discussing how to interpret the further development of client decisions and where the project would eventually be heading. Several members of the design committee expressed confusion and frustration that none of the designers participated in the steering committee meetings, that on the other hand were attended by several other non-committee members, especially from the DB-contractor’s organisation.

- The architects expressed some concern about the progress of the project. They found that criteria and previous decisions constantly changed and that they thus kept doing more and more work for free (since they worked on a fixed fee) which, so it appeared to them, only served to show some goodwill in the spirit of the partnering setup. The chief architect underlined that he had no problems with doing a lot of extra ‘free’ work on this first project, hoping that any possible losses would be covered by gains at the four following projects. He was, however, becoming increasingly sceptical regarding the profitability of the engagement and worried that the original idea of re-using e.g. apartment designs would be severely compromised by the frequent changes of the client’s mind and of decisions regarding design concepts. The chief architect emphasised that he respected the client and was unsuspicious towards the client’s intentions, but he questioned if the client organisation and its

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96 Interview with the design manager, Sept. 22nd 2003.
representative were fully aware of the consequences that constantly changing decisions, or lack of decisions, had on the architects and their work. He called for establishing a common understanding shared by the client and by the steering and the design committees, and he expressed his concern about the progress of the work conducted by the steering committee. He openly expressed worries that the steering committee was not sufficiently straightforward in its communication with the client: “A big part of these problems are because we treat the client as if we handled a rotten egg!”

- The discussions revealed that the designers had much understanding of the complex and difficult situation under which they knew that the steering committee had to operate. The designers felt that the series of the five projects was of great importance to all involved. The projects and the collaborative development initiative were of great symbolic importance and designers expressed understanding if the work of the steering committee was strongly influenced by political processes deriving from the companies’ individual strategic interests and agendas (for which the project series was important). However, the designers found it problematic that while, in their perception, the steering committee would be evaluated on a wide spectrum of partly intangible parameters embracing a much wider perspective than the five projects themselves, the design committee would be held responsible that the individual project would fulfil the far more tangible evaluation criteria of schedules and budgets. The chief architect was the member of the design committee most explicit in his formulations when he expressed that it, in his opinion, would be necessary that the project partners soon decided on how to progress with the project. He quite rhetorically formulated that in his opinion there was a need to decide on whether to maintain the great ambitions regarding the project, the collaboration principles and the division of responsibilities, or to alternatively propose that the project should be continued according to the construction industry’s standard agreements with all that this would imply of working with formal minutes of meetings and decisions etc. The question was obviously rhetoric because all companies involved actively worked on building/maintaining an image of capability for working under new innovative project structures and partnering agreements. For these efforts the current project was of high PR importance.

- The design committee concluded that the designers simply did not meet the client sufficiently often for enabling the design process to progress satisfactorily at these early stages when there were still many unsettled issues of vital importance to the further design activities.

At the design committee meeting on September 17th the design committee agreed that the design manager should bring up the issues regarding decision making and communication with his superiors and that he should request these problems to be

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97 Design committee meetings, Sept. 1st 2003; this statement was repeated during a later meeting on Sept. 17th.
considered by the decision makers (the DB-contractor organisation and the steering committee) so that the problems could be solved and the work progress. The outcome of this action could not be observed as the project was (temporarily) suspended only a couple of days after this meeting.

4.6.5. Subcontractor involvement

An introductory workshop, with participation from a few appointed sub-contractors, was held already in the summer of 2003, with the aim of engaging participants in the process-orientated approach. During this workshop (not monitored during this research) project participants from subcontractors (concrete, carpentry, installations, painters/decorators) and the DB-contractor’s staff brainstormed how they could all contribute to overall successful performance on site. As a result an explicit list of ‘this is how we are going to collaborate and these will be our attitudes’ was composed along with a ‘blacklist’ of behaviours, procedures and attitudes that the participants had committed to avoid.

At design committee meetings the appointed process facilitator expressed his personal scepticism concerning whether all the appointed subcontractors’ attitude to process-orientated cooperation was sufficiently positive for the project to be successfully executed in accordance with the fine intentions of collaboration. Based on his previous experiences with a couple of the subcontractors he expected them not to cooperate very well. However the design manager assured that he was confident about the chosen sub-contractors when he was, during an interview (Sept. 22nd 2003), asked about his own expectations of the future cooperation. He commented the process facilitator’s statements during the design meeting: “In this and other contractor companies one can ask about a specific sub-contractor and get ten different answers. It all depends on people’s personal first experiences from cooperating with the sub-contractor. If the people [representing the subcontractor] they’ve worked with are reliable and competent, the sub-contractor will be forgiven for almost whatever happens in the future. However, if meeting less competent subcontractor staff, no future good experience will rehabilitate the sub-contractor.”

Discussions in the design committee revealed what appeared to be a shared impression of the entire construction business as working according to the principle of ‘gaining on the swings what is lost on the roundabouts’: with prices levelled according to this principle several members of the design committee expressed their personal doubts that suppliers would eventually allow a well-organised and performing project to benefit from the collaborative initiative through lower prices and bids. Participants expected that subcontractors and suppliers would generally sub-optimise for their own short-term benefit, and in practice attach little importance to rather vague prospects of gaining future repetitive projects.

4.7. Summary of findings

The case study highlighted a number of issues relating to lean application and design/construction integration. These findings will be discussed further in Chapter 7. To summarise: this case study illustrated some of the challenges of achieving design/construction integration and to systematically approach the lean application from a wider project delivery perspective.

98 Design committee meeting Sept. 17th 2003.
Lean elements and integration indicators from the case will be summarised in the following:

**4.7.1. Lean elements**

From the data collection a number of ‘lean elements’ relating to the case project could be identified. Table 4.1 provides an overview over these findings. In addition to the more abstract principles of the lean philosophy the table contains a number of concrete tools, methods and procedures that are mentioned in literature as measures that can be applied to concretise lean initiatives (in manufacturing and/or construction).

<table>
<thead>
<tr>
<th>Lean design/construction element</th>
<th>Present in majority of processes</th>
<th>Present in some aspects</th>
<th>Not present at all</th>
<th>Contradictory</th>
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</thead>
<tbody>
<tr>
<td>Focus on optimising value for client and users</td>
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<td>Value stream mapping</td>
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<td>Value unambiguously interpreted in relation to end customer</td>
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<td>Waste reduction focus</td>
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<td>Approach value and waste from a system’s perspective</td>
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<td>Perfection aspiration</td>
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<td>Systematic experimentation</td>
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<td>Strategy for building continuous improvement into the process</td>
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<td>Strategy for making improvements permanent</td>
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<td>Strategy for strengthening learning and inter-organisational team learning</td>
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<td>Early supplier involvement in design</td>
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<td>Systematic reduction of variability</td>
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<td>Concurrent design of product and production process</td>
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<td>Production control on the entire design/construction process</td>
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<td>Simplify organisation</td>
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<td>Effective client involvement in design</td>
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<td>Set-based design process</td>
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<td>Process transparency in design</td>
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<td>Process transparency in production</td>
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<td>Measures to systematically enhance SC collaboration</td>
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<td>‘Pull approach’ to design</td>
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<td>‘Pull approach’ to production</td>
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<td>Long-lasting supply chain relations</td>
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<td>Cost reduction targets</td>
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<td>Securing of continuous work flow</td>
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<td>Levelling workload</td>
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<td>Last Planner System</td>
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<td>5S99</td>
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<td>Just-in-time (JIT) logistics</td>
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99 “5S” expresses five simple and popular principles often applied in lean manufacturing as good shop-floor practice. 5S is short for Sort, Set in order, Shine, Standardise, and Sustain.
Defect-detecting system (‘poke yoke’)
Systematic approach to stress system for identifying weaknesses

Table 4.1: Overview of the case findings in the perspective of widely common elements of lean application.

4.7.2. Integration indicators

As was discussed in Chapter 3, Baiden et al. (2006) describe a delivery team in a construction project as ‘fully integrated’ when it satisfies the criteria of Table 4.2. From this understanding of integration it is possible to summarise the case studies as follows:

<table>
<thead>
<tr>
<th>Project indicators of integration:</th>
<th>Present in majority of processes</th>
<th>Present in some aspects</th>
<th>Not present at all</th>
<th>Contradictory</th>
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</thead>
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<tr>
<td>Project delivery team with a single focus and objectives for the project</td>
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<tr>
<td>Project delivery team operating without boundaries among the various organisation members</td>
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<tr>
<td>Project delivery team working towards mutually beneficial outcomes by ensuring that all the members support each other and achievements are shared throughout the team</td>
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<tr>
<td>Project delivery team able to predict more accurately, time and cost estimates by fully utilising the collective skills and expertise of all parties</td>
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<tr>
<td>Project delivery team sharing information freely among its members such that access is not restricted to specific professions and organisational units within the team</td>
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<tr>
<td>Project delivery team with a flexible member composition and therefore able to respond to change over the duration of the project</td>
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<td>A co-located project delivery team with a new identity</td>
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<td>Project delivery team offering its members equal opportunities to contribute to the delivery process</td>
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<td>Project delivery team operating in an atmosphere where relationships are equitable and members are respected</td>
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<td>Project delivery team with a “no blame” culture</td>
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Table 4.2: Overview of the case findings in relation to indicators/factors of integration as identified by Baiden et al. (2006).
Chapter 5

Case II
5. Case II: Rehab-housing units in Denmark

This case study describes design of 112 rehab-housing units in Denmark. The project was studied continuously throughout the autumn 2004 and winter 2004-2005. In the spring of 2005 data collection was completed, shortly after site work had commenced. Case II examines a contractor-led approach to an integrated application of (a limited number of) lean construction methods to both design and construction. On this project the design/construction integration theme was dealt with under very complex organisational circumstances where lean-initiatives in the design phases were limited to addressing mainly technical issues of detailing. The case study’s primary focus is on the management of a detailed design process which the design-build contractor sought to organise for meeting the design intent, while also preparing for an efficient production process.

While the lean theme was relatively weakly represented, this case illustrates some of the challenges of obtaining an efficiently integrated value-delivery process in the case of a multiple stakeholder client body, characterised by complex inter- and intra-organisational relations of control and influence.

5.1. Case description

The project comprised 112 rehab-housing units that were a part of a new pensioners’ centre. The housing units were built with shared kitchens and facilities and, in connection to these, a number of meeting rooms, staff offices and other additional support facilities. The project was one of three sub-projects that together would form the new pensioners’ centre. The conceptual design had been developed by an architectural studio which had won an architectural contest for the design of the entire centre. Subsequent to the contest, the winning architects developed the conceptual design in cooperation with the client’s project organisation and the local municipality who would be a customer of the facility. The conceptual design was on a relatively high level of detail and formed the basis for the later tendering of the pensioners’ centre project. The overall project was divided in three (sub)projects, for which separate tender bids were invited for under a design-build model where bidding contractors were to provide a full delivery team including architects to finalise the detailed design. In addition to the 112 rehab-housing units another project dealt with delivering 40 ‘senior apartments’ and the third project dealt with facilities for cultural activities, physical exercise and sport etc. for senior citizens.

The tendering procedure was partly a ‘reverse tender’ where a price estimate was specified in the tendering material and the winning bid selected on a ‘best value’ basis though with price as the single most important factor. The project was subsidised with public funding and thus subject to a number of rules prescribing competitive tendering, third part examination of project material etc.

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100 As mentioned in Chapter 2, the original research strategy was to study this project through to completion. Due to unforeseen circumstances (re prioritisation of the researcher’s time for the benefit of commercial assignments) the data collection was brought to an end after the main design phases were completed.

101 This procedure is not uncommon in Denmark. For projects covered by rules prescribing contracts to be awarded through procedures of competitive tendering, this is one of several methods intended for motivating bidders to focus on value delivery through the application of selection criteria based on the ‘economically most advantageous bid’ as an alternative to the simple preference of lowest bid.
Three different design-build contractors won the DB-contracts tendered for the different (sub)projects. The three winning contractors had all submitted bids for all three subprojects, that were eventually awarded those having submitted the lowest bids. This case study focused only on the rehab-housing project.

The construction budget for the 112 rehab-housing units was DKK 77 million (EUR 10.4 million) and DKK 96 million (EUR 12.9 million) including VAT. This budget had been approved on the basis of an estimate from the client’s advisors/consultants. The gross floorage for the rehab project was approximately 8,000m². The detailed design was begun in June 2004 and the first turf was scheduled for cutting by the end of August the same year. The schedule was considered to be very tight, but necessary, for the centre to gradually being taken into use from summer 2005 when the facilities would be needed.

5.1.1. About the key participants

- **The client** is a local non-profit housing cooperation. The client operates within a small geographical region where it owns and operates a number of social housing estates and apartment blocks for low to medium income groups. For the client the new pensioners’ centre was an unusually big project and also within a field where the client organisation did not have previous experience. The client had hired an experienced external consultant to represent it in all communication with the design-build contractor (see below).

- **The client’s project consultant** was hired to manage the project on behalf of the client organisation. The consultant worked as a regional manager for another non-profit housing cooperation noticeably larger than that of the client. He possessed some local knowledge and considerable experience of managing projects with many stakeholders on the client-side (such as municipalities, housing organisations, residents etc.).

- **The municipality** is a medium-sized provincial city in Denmark. The municipality was a central stakeholder in the project since it was the customer/client of the non-profit organisation which constituted the project’s formal client. The new pensioners’ centre was to serve public welfare purposes, an area under the responsibility of the municipality. However, due to some specific circumstances (governmentally enforced expenditure and investment restrictions) the municipality could not itself acquire the pensioners’ centre. This was the reason why an arrangement where the client organisation would build, own and partly operate the facility, had come into existence. Thus the municipality was in many respects to be considered the actual client. Though listed here as one stakeholder, the municipality in fact participated in the project at different levels where it was represented through different bodies of which some were administrative (with the building authorities as the most important) and others political.

- **The client’s engineering consultant** owned a small local engineering consultant company. He was hired by the client to assist in a number of assignments related to the three projects of the new pensioners’ centre, and in
addition to this job he was involved in a number of other construction projects that were all part of developing a new area of town. The engineering consultant was heavily involved in the three subprojects where he did site inspection and took care of a number of other supervision and coordination activities on behalf of the client.

- **The architectural firm A** (hereafter referred to as *Architects A*), which won the architectural contest for the pensioners’ centre, is a medium-sized architectural firm that primarily operates in the business segment of housing facilities and different kinds of public care-taking institutions (kindergartens, care for the elderly, etc.). In addition to having developed the conceptual design, Architects A functioned as the client’s representative in coordinating the work of user groups and overseeing the development of the detailed design. This was to ensure that the project would benefit from the work and input of the user groups and also meet the design intent.

- **The architectural firm B** (hereafter referred to as *Architects B*) is a small to medium-sized architectural firm hired by the design-build contractor to participate in the development of the detailed design and produce the drawings and design documents.

- **The design-build contractor** (hereafter referred to as *the contractor*) is one of the largest contractors in Denmark. At the time of the case study the company had several years of experience in working and experimenting with process-orientated production systems and it was among the first contractors to adopt tools and procedures of lean construction for projects in Denmark. In addition to the coordination and control tasks of a DB-contractor, the company’s in-house department for structural engineering was to provide the structural design. (*The contractor is the same firm that was involved in the project from Case study I as DB-contractor*)

- **The engineering consultant** is a small- to medium-sized engineering consultant hired by the design-build contractor to provide the design of electrical and mechanical installations. Based in the city where the new pensioners’ centre was built, this company had local experience of working with the client and the municipality.

### 5.1.2. Background

Apart from the client, the municipality and their consultants, no formal long-term relations existed between the project parties, but the contractor (which is among a few large contractors dominating the Danish construction market) was occasionally involved in projects together with other organisations participating in the rehab project. The parties of the project delivery team did not have (formalised) long-term relationships.

The client’s project consultant/manager and the contractor’s design manager knew each other from another residential project that was about to be finalised. In this project they had operated as client representative and project manager, respectively.
This project was the pilot project for the contractor’s lean design concept\textsuperscript{102} and had represented the company’s hitherto most advanced attempt of executing a project with application of its lean construction concept throughout both design and construction.

The two designers representing the engineering consultant had some personal experience with working with the municipality and the local building authorities, but they had not worked together with any of the other designers prior to the rehab project.

5.2. Project organisation

The organisational circumstances surrounding the project were highly complex (see Specific project challenges, 5.3.1, below). On the side of the client the project activities were structured around a steering committee where representatives of the client organisation, Architects A, the municipality and the client’s project consultant took seat. The contractor did not have a seat in the steering committee, nor did it participate in the meetings of the committee that were chaired by the client’s project consultant.

The design committee was chaired by the contractor and had representation from the design and project manager, the project production/site manager, the chief structural engineer, two representatives of Architects A, two representatives of Architects B, and two from the engineering consultant who participated with an engineer responsible for the electrical systems and one for the mechanical. The client organisation did not participate in the work of the design committee but was represented by Architects A.\textsuperscript{103}

A characteristic of the project organisation was a fragmented authority regarding design decisions (discussed below). The basic project structure was design-build. The DB-contractor and Architects B were to produce the detailed design but all architectural aspects were to be approved by Architects A and all economical aspects by the client’s project consultant. – It took months of project work before the full implications of this was understood by the design committee (discussed below).

5.3. Project delivery strategy

It was of utmost importance to the client that the project could be delivered with control over the cost development, i.e. within budget. This was crucial as the client’s only source of income for this project (the fees for managing the real estate facilities of the pensioners’ centre) was fixed in terms of a contract with the municipality. The client’s strategy was to limit the financial risks by dividing the overall project in three individual subprojects (rehab housing, senior apartments, and leisure/sport/culture facilities), all executed under a design-build structure, and to have an experienced external project consultant to manage the project on its behalf.

\textsuperscript{102} Evaluated by By og Byg (2004).

\textsuperscript{103} The project started with the design manager also having the title and responsibility of project manager. However, during the design process the site/production manager took over the project manager role. No explanation was given to the design committee other than they (design manager and production manager) had found this to be practical. Both participated continuously in the work of the design committee and the shift of the project manager role did not seem to influence their work in the design committee.
On the DB-contractor’s side, the project delivery strategy was to produce a thoroughly worked through design with a high degree of buildability that would ensure an efficient production/assembly process on site. Through its own lean concept the contractor planned to enhance control and steering of the project development from design over construction. This lean concept primarily consisted of procedures for reactive work planning with the Last Planner System (Ballard 1994; 2000a). The design-build contractor had decided to let this project be one of several pilot projects where the company’s concept for lean design (which was still under development) should be applied throughout the design process. For some years the contractor had operated with its own site-orientated lean construction concept which was based on the Last Planner System. The lean design concept was essentially an upstream application of this tool and was intended to improve management of design task planning.104

5.3.1. Specific project challenges
The project was characterised by a remarkable combination of specific project challenges:

- **Complex organisational circumstances:** The project had an unusually large number of stakeholders, often with divergent needs and interests, and their internal relations were interwoven in a complex and to some degree non-transparent pattern that was difficult for outsiders to see through and navigate in. The organisational structure was further complicated by the inclusion of a few (external) consultants hired to manage the project and/or represent the client regarding specific issues. This added an extra hierarchal layer to the formal project organisation. Also the structures regarding contractual and managerial relationships were highly complex. The contractual basis for the project was a design-build arrangement (though a rather detailed conceptual design had been specified for the tender) where the DB-contractor entered with its own (subcontracted) architects, and the detailed design was to be developed under hands-on supervision from the architects who developed the conceptual design.

- **Ambiguity of the ‘client’ organisation:** The formal client was in fact a ‘front man’ of the municipality (the client’s customer/client and de facto initiator of the project) who was prevented from formally procuring the facility under public management. The municipality covered many stakeholders - administrative, operative and political - all represented in formal and informal project structures in complex and often opaque patterns.

- **Complex decision structures:** Many client-decisions, small as well as large, had to be carried through organisationally complicated (and often lengthy) processes. Often these required involvement of a large number of stakeholders and approval at several organisational levels. This was not always a formal requirement (in a contractual sense), but a managerial necessity not to dissatisfy influential stakeholders who expected to be consulted. Short-notice issues/questions could be very problematic since many stakeholders expected

104 See also Case I (Chapter 4) and Chapter 3 for descriptions of the contractor’s lean concept and the Last Planner System.
that such matters should be considered at the scheduled meetings (e.g. in a popularly elected political assembly).

- **External influence:** The new pensioners’ centre was subject to some attention from the local community where it was situated. At the local level it was also of some political importance (especially since it, in the eyes of the general public, was considered to be a public project) and it was not unlikely that interests of external stakeholders could lead to some kind of direct or indirect political interference with the project (e.g. through influence exerted on some of the project participants or key stakeholders).  

- **Tight schedule:** The design committee considered the project schedule to be tight, not least because of the often lengthy processes of communicating with stakeholders.

- **Site conditions:** The site conditions were difficult in several respects. The municipality would only allow for access to site from one side. The division of the pensioners’ centre into three subprojects with different DB-contractors was expected by the DB-contractor to significantly complicate coordination regarding site and delivery logistics. This would especially be problematic to the rehab project which was situated in the site corner opposite to the entrance. Additionally, the municipality (who coordinated the development of the area) had started by building the streets that had been completed with high kerbs and a narrow roundabout right before the entrance of the site. The contractor expected this to further complicate site access and was confident that the high kerbs would be badly damaged by heavy construction machinery. Construction took place over the winter 2004-2005 and the site was extremely muddy which provided some technical problems for construction.

5.4. Findings

The case study provided a rich collection of data and a large number of interesting observations and findings could be extracted. For this research some of the most important were:

- Partial implementation of the Last Planner System in design
- Participant engagement and collaborative design
- Fixed design a source of uncertainty

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105 In Denmark public projects are usually executed with strong participation from users and organised interest groups (e.g. external stakeholders and internal employee representation on several levels).

106 An important aspect of this was that the presence of three different DB-contractors was likely to make it impossible to identify the party to bear the responsibility for damages. The DB-contractor’s project staff predicted that this could generate conflict and dispute between the municipality, the (formal) client organisation and the contractors, which would be a source of significant dissatisfaction to all parties. The design manager was aggravated by this issue which he considered as completely unnecessary and perfectly avoidable.

107 It is not unusual for Danish sites to be muddy, especially during winter, but this was an extreme example. It appeared to be a common opinion among project participants that they had never before experienced such bad mud conditions. Already at an early stage did the contractor exceeded the budget for covering expenses related to winter activities.
5. Case II: Rehab-housing units in Denmark

- Diverting interpretations of the demand for ‘environmentally correct design’
- Participants perceiving divergent signals from the municipality
- Limited transparency of project economy and decisions
- Management with maximum control of economy and schedule
- Debate and conflict over technical issues
- Development of client/user expectation (expectation management)
- Differences in perception of important issues
- Facilitation

These themes will be discussed in the following:

5.4.1. Partial implementation of the Last Planner System in design

Though being the main tool of the DB-contractor’s lean design initiative the Last Planner System (Ballard 1994; 2000a) was not fully implemented in the design phases. The work of the design committee was structured around a design schedule produced by the DB-contractor (with input from the design committee) at the outset of the design phase. Weekly work plans were updated by the design manager on the basis of task completion lists that design committee members submitted via email. Look-ahead planning was primarily taken care of by the design manager (in bilateral coordination with designers) and not a separate topic for structured discussion at design meetings. An interesting observation was that it was typically around issues related to tasks/assignments with long completion/lead times that internal design coordination was troubled.\(^{108}\)

Based on PPC\(^{109}\) estimates submitted from designers to the DB-contractor, the design/project progress in comparison to the weekly work plan was occasionally mentioned in brief by the design manager. He often had to remind and reprimand the designers to submit their PPC charts (and to do it in time since it was sometimes difficult for him to get the overall PPC charts ready prior to the weekly design meetings). The overall PPC chart, including the feedback from all designers, were either submitted by email or distributed at every design meeting. Unless there was a need for the design committee to collaboratively solve a specific planning problem PPC was usually not discussed. Root cause analyses regarding plan deviation were not conducted.

Though not being a very visible theme at design meetings, several participants occasionally mentioned that they found the reactive planning and the task lists useful since it helped them keeping an overview of how the project progressed.\(^{110}\)

\(^{108}\) Typical examples concerned technical details that, often through a chain of cause and effects, would influence critical assignments as e.g. the design of the prefabricated elements. One simple example concerned discussions about choosing certain wall lamps. This would imply different switch sockets (intended hidden in structural columns), that would require a different design of the prefabricated columns. This would require redesign of the columns in time for the element supplier to prepare for production and timely delivery. Such issues with implications for long planning cycles commonly provided some unexpected challenges.

\(^{109}\) PPC (Percent Planned Completed) is an estimate of conformance between plan and task execution, see Chapter 3 or (Ballard 2000a).

\(^{110}\) A few times this was mentioned by individual designers during the design meetings, and a few mentioned the lean concept in the questionnaire replies. Interestingly, the designer who most often brought up the lean concept and the PPC charts as something positive, at one point expressed that he feared that the system could mislead project participants to be less attentive regarding coordination if placing too much trust in a system to catch potential problems (design committee meeting, September 8th 2004).
5.4.2. Participant engagement and collaborative design

Throughout the observation period all permanent participants in the design committee exhibited engagement in the general project design and they spent much time collaboratively discussing technical as well as value-related issues. During meetings the individual participant often engaged in design discussions that did not directly concern his/her technical discipline and/or formal area of responsibility, especially concerning questions of establishing a common understanding of what would in practice represent best client and user value achievable. Design discussions often revolved around several aspects simultaneously. Most common appeared to be aspects of value delivery, constructability/buildability, cost impact, and supply issues (e.g. delivery time for materials chosen).

The two different architect teams appeared to collaborate well. Architects B identified many possibilities for design improvements and in several cases they discovered errors and omissions in the conceptual design. The design committee members from Architects A were very open to the inputs from Architects B and though the architects did not always agree on what would be the aesthetically most preferable solutions, they were very active in collaboratively seeking to optimise value delivery.

5.4.3. Fixed design a source of uncertainty

The architect representing Architects A in the design committee did not have full authority to speak on behalf of this company and its position regarding the building design. Other architects from Architects A had developed the schematic design and in some cases the representative stated that he did not possess the mandate necessary to approve a certain design change without approval from the colleagues who had originally developed the concept. One example of this situation was connected to the sudden discovery that some offices were designed so that the only possibility of natural ventilation would be through a narrow window that could open no more than max. 10cm. The design committee, including the representative of Architects A, found this detail very problematic and it was concluded that a design change was absolutely necessary to ensure a bearable indoor climate during summer. The design could, however, not be modified before permission had been obtained from the conceptual designers. The representative in the design committee promised that he would ‘lobby’ his colleagues for accepting design modification but he could not promise that he would be successful. The design committee thus had to proceed without immediate clarification on this point. It was, however, at no time observed that the restricted mandate of the architect representative in fact resulted in any problems deriving from his decisions/approvals being over-ruled within his own organisation.

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111 One example of an omission in the conceptual design was that all doors were standard doors without protection against the considerable wear and tear that wheel chairs would expose on them. This was discovered by Architects B and led to a design change.

112 A design committee representative from Architects A several times emphasised his interest in the detailed design adding as much value as possible to the conceptual design. He found that Architects A would anyhow be the ones who would be evaluated on the qualities and blunders of the facility when in use.

113 Design committee meeting 3, August 11th 2004.
5.4.4. Diverting interpretations of the demand for ‘environmentally correct design’

In the tendering material it was stated that the project should be designed from ‘environmentally correct principles’ according to a newly released system “Manual on Environmental Management in Project Design”\textsuperscript{114} with which none of the members of the design committee had previous experience. The demand for ‘environmentally correct design’ became the subject of much discussion and consideration in the design committee and in the negotiations between the DB-contractor and the client-side of the project organisation, including the municipality.

A number of aspects regarding this issue deserve elaboration since they illustrate how the lack of a common understanding and shared expectations regarding one single design criteria can have far-reaching consequences for value delivery, for design and production planning, and for the cooperation between client and stakeholders and the project delivery team.

- **Asphalt-based base felt:** Use of asphalt-based base felt for the roof construction was debated over a long period of time. At an early stage the design committee had decided on using an asphalt-based product because it was the technically best solution and considerably easier to assemble correctly than the alternative plastic product (which the design committee feared could by time provide failure and moist damages). However, the municipality’s office for construction works (which was the local building authorities) was resistant (possibly from pressure from other units of the municipality) to grant permission for using asphalt-based construction materials as roofing base felt because asphalt is considered a problematic material in terms of disposal. The municipality found that a solution with asphalt-based materials did not fulfil the demand for ‘environmentally correct design’. The design committee (including Architects A that represented the client) was very surprised about the municipality’s persistence in refusing to accept the roofing felt, and the contractor was not willing to accept this position. The contractor and the design committee recognised the disposal problems regarding asphalt-based materials but found that asphalt’s technical qualities by far exceeded this disadvantage. The contractor argued that the product was supposed to last for many years and that the asphalt volume in the product was completely negligible in comparison to the large amounts of asphalt the municipality was using for its roads.

Since the client was formally a private organisation, the municipality’s resistance to approve asphalt in roof constructions was finally broken since the municipality did not deny other private clients the right to use nationally approved asphalt-based materials for their buildings, and hence the municipality in fact could not discriminate in relation to this particular project. Processes of negotiation regarding this question took considerable time and effort. To the contractor this was problematic since it delayed the ordering of prefabricated roof coffer modules. Over several meetings (including a meeting with the client, represented by the client’s project consultant)\textsuperscript{115} this issue was

\textsuperscript{114} Applied through the so-called ‘ABC Planner’ programme.
\textsuperscript{115} Extraordinary project economy meeting, October 8\textsuperscript{th} 2004.
discussed and in general project participants expected that the municipality would eventually give in, but the lack of certainty naturally implied risks to the contractor who was forced to gamble by continuing designing and counting on eventually obtaining approval. With the tight schedule, a delaying of the decision would have lead to other misfortunate consequences for the project and the contractor.

To the municipality the eventual approval of an asphalt-based solution was affiliated with a value aspect since it contradicted a new and highly profiled environmental policy regarding the municipality’s real estate projects. Due to the nature of the project and the municipality’s role as the actual client/customer this was considered a loss of client value by the municipality. The design committee assessed that aspects regarding prestige of the building authorities and other units of the municipality had contributed significantly to the dispute.

- **Lighting and illumination technique:** The installations for lighting and illumination were specified on a very detailed level in the tendering documents. During design committee meetings the engineer responsible for designing the electrical systems occasionally expressed that he did not find the solutions specified in the tendering material to be coherent with the strict environmental demands otherwise enforced by the municipality. The specified lighting and illumination equipment contained a high number of spots and glow lamps of types of relatively low energy efficiency. This was first brought up by the electrical engineer when the design committee started to discuss how the designers should interpret the environmental policy and demands that the project was subject to. At later meetings (when the issue of environmentally correct design was generating some conflict between the DB-contractor and the municipality) the electrical engineer expressed some frustration that the client and municipality maintained, what he considered to be a very rigid interpretation of environmentally correct design regarding a few details (e.g. in the case of asphalt-based materials, as addressed above), when the environmental impact of other technical issues was just disregarded.

- **Client/stakeholder expectations:** Though being aware of the tendering material’s demand for ‘environmentally correct design’ the design committee at first failed to realise the actual importance ascribed this design criteria by the municipality. One reason for this was that it was considered a widely common practice for clients (not least those from public, semi-public or the NGO sector) to have the tendering material exhibit politically correct ‘show-off’ policies regarding environmental issues. It was the experience of the design committee that such policies are usually a) open to interpretation and b) rarely enforced, especially if contradicting with economical or quality-related project values. In the specific case the budget was considered to be relatively tight and it was obvious that the quality and physical performance of the facility was absolutely crucial since the housing organisation (the formal client), that was to own, maintain and partly operate the facility, could suffer difficulties covering operation costs should these exceed what had been predicted. On this background this theme had not been expected to become an
issue of dispute.\textsuperscript{116} This did not mean that the design committee was indifferent to the environmental impact of the facility (often this aspect was brought up during discussions when different potential design solutions were being compared)\textsuperscript{117}, but it implied that the design had developed to a relatively late stage before an important aspect of stakeholder value was identified by the design team.

One reason for this misjudgement by the design committee was the complex organisational framework where the municipality (which had adopted and promoted a new policy for a ‘green profile’) seemed to consider itself the actual client\textsuperscript{118} and where it was difficult to see through the decision processes on the client’s side over which the municipality possessed considerable influence.

- **Learning:** One result of the dispute over the use of asphalt-based materials was that it contributed considerably to the design team’s understanding of the organisational project framework and of individual stakeholder values and positions. The design team members, that for some time had been frustrated with feeling that they did in fact take environmental aspects seriously without this being acknowledged by the municipality, ended up concluding that much of the dispute with the municipality could be resolved by writing explicitly (in the project material they submitted) about how the environmental aspects of the design had been considered, and by arguing explicitly for their design choices. This appeared to considerably improve cooperation regarding the achievement of design approvals.

Although the design was on a relatively late stage, the design team members collectively took an intensive course in the “Manual on Environmental Management in Project Design” and the tool ‘ABC Planner’. During discussions at late design stages designers often made reference to the learning outcome of the troublesome processes of reaching common understanding and agreement on ‘environmentally correct design’, of what really mattered to the client and municipality, and of how to navigate in the complex organisational context of the project. Design committee members often expressed some annoyance that the process had been so lengthy and dissatisfactory to all parties and that the hard-earned learning would be of limited benefit since the

\textsuperscript{116} It should be mentioned that one of the environmentally most important aspects of Scandinavian buildings is that of their energy efficiency. In an international comparison the Danish building codes are very demanding regarding heat loss etc. Besides, the combination of a cold climate with a long winter and the very high Danish energy prices provides a considerable incentive for energy efficient building design.

\textsuperscript{117} It is common for building designers in Denmark to consider it good practice to always consider environmental aspects as a natural part of designing. However, after issues of environmental awareness in design had become a source of considerable dissatisfaction from the municipality, the design committee decided to always add ‘environmental aspects’ as a separate point on the design meeting agenda and in the minutes. The purpose was to send a positive signal to the municipality which occasionally complained that the issue was not taken seriously neither by project delivery team or by the (formal) client organisation.

\textsuperscript{118} During meetings the client’s project consultant often emphasised that the designers and the contractor should consider the municipality a second client equal to the formal client.
two other subprojects were to be executed by different DB-contractors and design teams.\textsuperscript{119}

An interesting observation was that environmental aspects of the facility became a very big issue and all in all ‘environmentally correct design’ was probably the single most explicitly promoted value parameter (apart from budget and schedule conformance). Nevertheless the overall procurement strategy with a highly specified conceptual design in fact limited the delivery team’s possibilities for systematically working according to this value. The municipality’s approach to the environmental theme was obviously of more political and rhetorical character than it was substantial. Though pushing very actively for the delivery team to adopt specific initiatives\textsuperscript{120}, the overall environmental impact appeared to be of remarkably modest interest to the municipality. This was illustrated in the little interest in energy efficient electrical and mechanical installations. As the project progressed the delivery team became increasingly focussed on limiting the risk of being exposed to difficulties by actively seeking to please the municipality in relation to environmental aspects. Eventually the production manager personally ensured that not even a single toilet seat of the facility would contain PVC (a material that was in general banned by the municipality that feared chemical diffusion between plastic materials and the human body) but with other technical details he ended up (much to his annoyance) using materials that he himself found were undesirable from the perspective of working environment, only because it appeared that these specific solutions could be easily approved by the municipality.\textsuperscript{121}

\textbf{5.4.5. Participants perceiving divergent signals from the municipality}

During the design process both the DB-contractor and Architects A (through their position as client design advisors) had frequent contact to the municipality. Over several months and many (weekly) meetings in the design committee it was a topic of (often informal) conversation how to interpret the signals from the municipality which was represented by different units in connection to different activities related to the construction project. In the client’s own project organisation the municipality was actively involved and represented by the department responsible for eldercare and in some respects also through the department responsible for infrastructure and facilities. The latter department was involved through two different offices where one (in charge of e.g. facilities management) was actively involved in the project while another was in charge of permissions and building approvals. The contractor felt that signals received from the municipality during project discussions did no match the experiences when applying for approvals, especially if this included exceptions from the general codes.\textsuperscript{122}

\textsuperscript{119} In the words of the mechanical engineer: “Finally we know how to deal with this. – A damn shame that we’re not to do the other two projects, because now we could do it really well…” (Author’s translation from Danish) (Design committee meeting, Oct. 20\textsuperscript{th} 2004).

\textsuperscript{120} In addition to the examples discussed above, other examples was when the municipality at some point pushed for the contractor to add recycled materials in the concrete (which the design team decided to avoid due to risk that pollution in recycled ingredients would provide quality problems, e.g. if oil remnants would by time spatter concrete surfaces). (Design committee meeting, January 5\textsuperscript{th} 2005).

\textsuperscript{121} Design committee meeting, January 5\textsuperscript{th} 2005.

\textsuperscript{122} It is common for construction in Denmark that some exceptions from the general codes are granted. In this project there were some specific needs for permission to compromise some codes (e.g. the
Several approval processes were problematic. The members of the design committee found that it was more difficult than usual to deal with the authorities, and that this particular project was characterised by considerably less pragmatism than usual when permissions were requested. The design committee members were generally frustrated about the situation regarding the cooperation with the building authorities. The difficulties did not surprise the members of the design committee who had experience from previous local projects and therefore knew of the officer in charge of approvals.

As the project progressed and the cooperation with the municipality’s department for construction continued not to be smooth, which was a permanent conversation topic in the design committee, discussions indicated that the committee members had developed a shared perception of the communication and cooperation problems deriving from influence of three main factors:

- Changes in some of the municipality’s offices internal positions of power/status influenced dynamically the municipality’s position as the project progressed;
- Lack of pragmatism from the officer in charge of granting building approvals;
- The design committee’s late realisation of what were the most important value parameters to stakeholders of the municipality, and hence insufficient communication of the motivation behind choices regarding design solutions and project planning.

5.4.5.1. Approval processes as an instrument of punishment?

In the autumn of 2004 it was at several occasions informally discussed in the design committee if the municipality used its position as building authorities for putting additional pressure on the project delivery team. The design committee felt that there were too many examples where the building authorities had made unreasonable and unfair demands regarding project material and documentation. Two of these examples were:

conceptual design, that was approved by the municipality prior to inviting for tenders, exceeded the heat loss code with 11%, which the parties expected would be accepted by the building authorities, not least because other factors, such as a high degree of sunlight absorption, would add a positive heat contribution. In other cases exceptions from technical codes were feasible if the codes were based on assumptions that would contradict the actual use of the facility. One example could be the ventilation capacity for passages or corridors where it was obvious that doors would anyway be left open the majority of the time).

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123 A number of approvals had to be achieved at different stages during the project: planning permission, project approval, permissions for starting excavation works and for casting, design approvals, approval of starting the construction process, and commissioning approval.

124 According to the descriptions he was “quite a character” who slavishly followed procedures, codes and policies as he interpreted them and who was very difficult to make consider specific aspects in relation to their wider contexts when asked to approve exceptions from the codes. Members of the design committee considered his approach to be very unusual for construction authority officials in Denmark, and they often discussed if his way of working was rooted in a different culture (he was found to speak with a distinctive foreign accent) and if it could be that his background was German? (Design committee members considered German construction professionals and bureaucrats to be less pragmatic than their Danish colleagues). – The discussions among the designers indicated that they did not suspect the official of acting in bad faith or of lacking technical/professional competences, and it appeared that such discussions were grounded in a wish to get to understand better the official and to find ways of improving the communication with him and his office.

Bo Jørgensen (2006)
The DB-contractor had to rent and dig down a waste water tank on the site because the municipality kept denying the contractor permission to connecting to the public sewage system. When the design committee was informed about this, several project participants recommended that the DB-contractor followed standard practice and put site work on hold until a solution had been reached. The representatives from the DB-contractor agreed that such confrontational reply might have been the formally correct step to take, but as the production manager put it “I principally do not wish to work in such a manner”. It was agreed that the situation was indefensible and unsustainable and that solutions should at first be pursued through seeking support from influential project participants or stakeholders who, as was the hope, could push the municipality for granting necessary approvals in the interest of the project.125

Another occasion where the possible motives of the municipality and building authorities were discussed by the design committee was when the building authorities, instead of approving the façade fittings for a balcony, wrote the DB-contractor that they wanted to see a full calculation and documentation for its thermal impact on the construction. The entire design committee agreed that this demand was ‘way out’, not least since the structural engineers had made what was considered ‘a very elegant solution’ where the sectional irons could be fully wrapped in insulation material in almost full length. All designers agreed that it most probably could not be done any better and that an additional heat loss calculation would be nothing but a waste of resources. The design manager suspected that the letter from the building authorities was an indication that the officer in charge had felt his toes stepped on by the project delivery team. The design manager would therefore contact the officer for a talk about what had motivated the letter and if there were misunderstandings or communication breakdowns that could be sorted out.126

5.4.6. Limited transparency of project economy and decisions
Apart from the contract sums etc. the economic frame of the project was kept under wraps. The client organisation had a contingency budget for unanticipated project changes etc. but the size of the sum was strictly confidential. Architects A expressed some frustration over this issue because they (who represented the client in the design committee) found that the missing information was an obstacle to their efforts of optimising the project in terms of value delivery. The client’s project consultant/manager refused to give in to the wish from Architects A because he and the client organisation had decided to keep this financial information strictly confidential throughout the project period.127 This was motivated by fear that this information was likely to be used by the many stakeholders to push for project changes to suit individual agendas and interests, and that this could have significant negative impact on effective management of the project.

125 Design committee meeting, October 20th 2004.
126 Design committee meeting, January 5th 2005. – The data collection was not continued into later project phases why the outcome of the meeting is not known.
127 Client steering committee meeting, September 29th 2004.
5.4.7. Management with maximum control of economy and schedule

In the words of the client’s project consultant, the project management setup “reflected the unusually complicated organisational circumstances regarding the project” under which he saw no alternative to stringent management regarding all questions of economical importance and/or consequences to schedule, in order to “avoid the project leaving the rails”.128

Two interesting observations from the most hectic design phases were:

- Events during the autumn of 2004, however, revealed that project participants had different expectations regarding the importance that the client’s project management approach would have on design decision processes. One of the most important issues in this respect concerned questions regarding facilities for rubbish depository and collection. Demands from key interest groups resulted in the design team adding rubbish chutes and a container depository to the project.129 In addition to several consequences for design and production planning this brought some extra expenses into the project in terms of production costs and compensation to Architects B for having been forced to redesign parts of the project. The DB-contractor got itself an unpleasant surprise when the client (represented by its project consultant) put the foot down and at first refused to approve the claim by the DB-contractor.130
  It was decided to arrange an ‘extraordinary project economy meeting’ to discuss the situation and to try to pull the chestnuts out of the fire regarding the relationship between client and DB-contractor.131 The meeting appeared to serve three purposes: reach a solution regarding the extra expenses (of which the rubbish disposal system and the addition of extra firewalls132 were the biggest); reach agreement regarding client approval processes, and; sort out issues and future procedures of cooperation between the client and the DB-contractor. The meeting was held in a positive atmosphere where all three parties133 expressed their understanding of the position of the others, and much oil was poured on the troubled waters. The outcome was that the client’s project consultant agreed to provide a lump sum to cover the extra expenses for the redesign, the firewall and for the rubbish chutes. The parties also agreed to meet more often and work to improve their communication.

The DB-contractor had, however, hoped for an agreement regarding faster approvals regarding the design as this would gradually develop. Eleven design meetings had been held and meeting minutes submitted to the client and its representatives. Architects A had participated in all meetings as representative

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128 Extraordinary project economy meeting, October 8th 2004.
129 Discussed below.
130 During a project meeting (held in a tensed atmosphere, September 29th 2004) the client’s project consultant made it clear that a decision was not a decision before it had been approved on the official project meeting and appeared in the minutes.
131 Extraordinary project economy meeting, October 8th 2004.
132 A demand which had been made by the local fire department.
133 Participating in this meeting were the design manager and his superior (head of the section at the DB-contractor), the two project coordinators from Architects A, and the client’s project consultant (the client organisation did not itself participate).
of the client and the design had progressed in their agreement. On this background the DB-contractor found that it could not but expect that the design was approved by the client. The client’s project consultant nevertheless insisted that regardless of what had been decided regarding design, all questions of expenses should (if deviating from the budget) be approved by him personally. Everybody agreed that ‘stop-and-go’ design would be a catastrophe to the progress of the project and should be avoided. The DB-contractor therefore pushed for a solution where the client would be represented in the design committee by someone with procuration/authority to also approve the financial implications of design decisions. Though the client’s project consultant expressed his understanding of this wish he refused to enter such arrangements (with the argument that it would require unreasonable resources) and he maintained that all economical implications were to be approved by him personally. It was agreed to enhance communication and make sure to meet in person if necessary to avoid future problems from escalating. The outcome of the meeting was not fully satisfactory for the DB-contractor who, despite the common understanding with the client’s project consultant, would need to continue working while bearing the full risk in case lengthy approval processes would bring the project and its progress into trouble.

- Project meetings between the client organisation and the DB-contractor were rare and short (for a beginning only one hour, which the parties however ended up agreeing had been insufficient in the situation where many issues were unresolved). Usually project progress meetings were held on the construction site and were each succeeded by a steering committee meeting. The setup was peculiar. In the beginning the project meetings had participation from the (formal) client and its project consultant, the municipality’s social affair’s committee, Architects A, the client’s engineering consultant, and the DB-contractor. When continuing to the steering committee meeting, this would take place without participation from the DB-contractor. The client’s project consultant insisted that all communication between the formal client and the DB-contractor should go through him, and he was very dissatisfied when once a letter (though of minor importance) had been sent from the DB-contractor directly to the client. When, during the autumn 2004, the pressure on all parties increased and the project continued to become more conflict-ridden, he and the client organisation agreed that henceforward the

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134 One of the Architects from Architects A (who coordinated the users’ committee and always participated in the work of the design committee) openly declared that he felt very uneasy about the situation. He too had been of the impression that design had progressed with the client’s acceptance and he did not want anyone to believe that he, when participating in the design committee meetings, was “sailing under false colours.”

135 The client’s project consultant was very careful to emphasise that this should not be understood as if he did not trust the DB-contractor or its representatives. Nevertheless his experience with managing projects of such complexity had taught him that there was no alternative to maintain rigidity regarding official approvals.

136 One conclusion from the extraordinary project economy meeting, October 8th 2004 (discussed above).

137 Such arrangement is uncommon for a steering committee when the project is executed under a design-build contract. (For an introduction to the concept of steering committees at projects in Denmark, see Case I (Chapter 4)).

Bo Jørgensen (2006)
official project meetings should take place without the presence of the formal client. At one occasion when a whole delegation from the client showed up on site 10 minutes early for a steering committee meeting and the project progress meeting was still ongoing, the client consultant kindly asked the client to leave and come back when the project meeting was over (and the DB-contractor would have left). - Thus the formal client and DB-contractor were without direct contact.

5.4.8. Debate and conflict over technical issues and design decisions
A large number of technical issues and design decisions generated a lot of discussion and negotiation etc. and some became topics of regular conflicts between some project participants and/or stakeholders. The following examples were themes of considerable discussion and required extensive resources from the design committee:

- **Ventilation volume**: Ventilation design was a challenging theme throughout the design process, not least because it was difficult to achieve an agreement with the municipality regarding ventilation capacity. For living rooms in the shared facilities the municipality had demanded a ventilation solution enabling a minimum exchange air of multiple times 140 l/min\(^{138}\) (dependent on size, number of users, smokers etc.) through natural ventilation. The natural ventilation capacity acceptable should be established via calculations from a principle which was specified in the tendering documents. From the beginning of the detailed design work the design committee identified this as a problematic issue. Reaching such high rates of air exchange would require relatively big installations and advanced skylight automation, it could create draught problems and it would result in a very high heat loss. The design committee almost immediately concluded that the 140 (120) l/min demand was unsuitably high. For a long time this specific question was the centre of much attention at design committee meetings and the contractor and the engineering consultant negotiated continuously with the municipality’s building authorities in the hope to achieve permission for reducing this demand. Agreement was not reached when the data collection of this research was interrupted, but in October 2004 the building authorities (while still maintaining their principle for determining the minimum exchange of air required) sent the DB-contractor a letter with proposals for assumptions on which to base the calculations. This letter and its proposal were interpreted differently among the designers, and interestingly a representative from Architects A suggested that the proposal could be seen as a conscious attempt of opening for a compromise. On the authorities’ list of assumptions appeared as little as four smokers for a large TV and activity room. This number was obviously unrealistically low but could perhaps lead to a significant (though still insufficient) reduction of the ventilation capacity demanded.\(^{139}\)

Similar demands were made in the case of the kitchenettes that were planned for each rehab unit. Though the case concerned small kitchenettes (to be installed in rehab homes where the occupants were not to cook) the building

\(^{138}\) Later modified to 120 l/min.

\(^{139}\) Mentioned under the extraordinary economy meeting, October 8\(^{\text{th}}\) 2004.
authorities at first required that the mechanical ventilation could provide an exchange of air of 140 l/min (which they later offered could be reduced to 120 l/min) as if it had been real kitchens. The design committee found the demand to be absurd and concluded that if the municipality would not eventually modify this demand, the installations of kitchenettes would have to be given up. This was however affiliated with a significant value loss to the users who had been promised kitchenettes, and in reality such step would not change the actual need for ventilation from the locations concerned since the occupants were expected to anyway install electric kettles, coffee machines and possibly even microwave ovens and/or a hotplate or two. The design team perceived the whole affair to be absurd, not least since there (according to the mechanical engineer) were anyway no sufficiently exact way of measuring or assessing the net ventilation in relation to the kitchenettes.

- **Heat loss:** From the start of the detailed design it was known that the overall design exceeded the maximum heat loss specified in the national building code (BR-95) with 11%. At the project start-up workshop in June 2004, where all key stakeholders (including the municipality) were represented, this was known to require a dispensation which it was agreed should be pursued as soon as possible. The exceeding of the heat loss specified was not expected to be a very big problem since the project also had good possibilities for accumulating energy from e.g. sunlight through the window areas. Participants therefore felt relatively confident that the net heat loss was going to be within acceptable range. Nevertheless, the process was relatively lengthy and troubled and involved a number of negotiations, recalculations etc. (discussed above).

- **Sun shielding:** Passages between blocks of rehab units were long and narrow and had very large glass areas. Nevertheless the conceptual design did not have any sun shielding. This was not an omission by mistake but a conscious choice by designers of Architects A, who wanted the passages to have a transparent appearance. From the beginning of the detailed design the design team identified this as problematic and even the two representatives from Architects A expected that design modifications would eventually be necessary. These representatives emphasised that they were loyal to the winning conceptual design (which had been worked out by some of their colleagues in charge) and that they would support its principles as far as possible. However, they admitted that they had not agreed in the decision to omit sun shielding since they expected that such solution would not work out. A thermal calculation was done by the engineering consultants and it left no

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140 This case was another example where the design committee tried to analyse the motives behind the demands of the building authorities. Also in this case the conclusion was that the situation reflected that either the municipality or the authorities’ officer was dissatisfied about something more than the specific issue disputed. The DB-contractor decided to bring forward the issue with the client’s engineering consultant who was found to be a very influential person locally and who could sort out such problems by pulling the right strings.

141 Design committee meeting, January 5th 2005.

142 Project kick-off workshop, June 17th 2004.

143 The representative from the social affairs’ office, who participated in the workshop, did emphasise that the municipality had not done calculations on the heat loss, and that the municipality could not be expected to do so. No indication of disapproval of the code excess was given during this workshop.
doubt that some sort of sun shielding would be absolutely necessary. Different proposals for solutions were brought to the table by different parties, and a lot of them were dismissed since they were found to conflict with the design intent (as this was explained by a representative from Architects A).¹⁴⁴ The design team tried to identify solutions that would be aesthetically acceptable, durable over the long term, and that were appropriate in relation to FM issues such as cleaning. This was not easy due to limitations of the existing conceptual design. The representatives from Architects A could not themselves carry a decision on what could be accepted, but had to bring back the thermal analysis to their colleagues, the conceptual architects, and ‘negotiate’ with them about what solution could be accepted.

- **Rubbish chutes:** The winning design concept operated with outdoor containers for rubbish. However, a number of circumstances led to a modification of this concept. One factor was that a rough estimate suggested that more containers than had originally been anticipated by Architects A would be necessary. Aesthetically this was undesirable. Another factor was that the staff of the centre demanded a more ‘staff-friendly’ solution and they preferred to have rubbish shafts. Another group of stakeholders were the rubbish collectors who demanded that rubbish could be collected from the facades for easy access and minimum manual handling. However, shafts would be a problematic solution since the municipality’s environmental policy required sorting of rubbish which did not match a single shaft solution (and multiple shafts would be much too expensive and space demanding). One, obviously controversial, solution to this problem that the design team considered to have investigated was to have the client organisation subcontract rubbish collection to a private company, instead of operating with the municipality’s refuse collectors. Hereby it would perhaps be possible to operate under the rules for private business organisations where rubbish sorting was not compulsory.

When the final approval of rubbish chutes was discussed on a meeting in the steering committee, the municipality and the client could not agree on who should bear the extra costs for this expansion of project scope. The municipality found that the project budget had to cover the costs, but the client and the client’s project consultant insisted that the rubbish chutes had not been part of the original tender through which the municipality had subcontracted the pensioners’ centre to the project client. Thus they found that the municipality would have to bear the extra costs. However, the municipality’s representative (from the social affairs’ office) could not sign for such a decision. A priced proposal would need to be presented for approval by the city council’s committee on financial affairs.¹⁴⁵ Though dealt with as soon as at all possible, this approval process took valuable time when design would need to continue without final clarification on this essential issue.

Many aspects (of technical, organisational as well as political character) influenced the process of identifying a solution, which would necessarily

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¹⁴⁴ An example of an unwanted solution was awnings, which conflicted with the architectural concept.
¹⁴⁵ Steering committee meeting, September 29th 2004.
5. Case II: Rehab-housing units in Denmark

redesign and extra costs.\textsuperscript{146} From the perspective of design/construction integration the process had considerable implications for preparing ground works and for preparing production of prefabricated elements. Clarification also had implications for the assignments connected to the redesign processes necessary.

- **Dimensions of floors:** From the very beginning of the detailed design process did the engineering consultants and Architects B express that they found the dimension of floors and the floor-to-ceiling heights (that had been specified by the conceptual design) to be inappropriately modest, and they often experienced considerable difficulty fitting the technically installations in the floor structures.\textsuperscript{147} Many of their concerns regarded buildability aspects and especially the engineers were uneasy about the risk of failure in installations deriving from practical difficulties of correct installation. The very modest floor thickness had some implications for the design process. Since the space for installations was found to be absolutely minimal at several critical locations especially the mechanical engineer occasionally needed to know several not yet specified design details in order to design installations that it would be practically possible to fit in the construction. Similarly Architects B needed to know in detail the design of the installations in order to develop design details that would allow the fitting of the installation. This situation demanded extensive coordination between the engineers and the architects.

There was not much that could be done about the narrow floor dimensions (that had been kept at a minimum to favour the external architectural appearance) but the representatives from Architects A did not find that the narrow dimensions were a problem as big as the engineering consultants found it to be. From discussions it nevertheless came up that Architects A in several places had designed from the assumption that it would be sufficient with installation pipes smaller than those the engineers concluded were necessary for the installations specified by the tendering material. Differences in opinion seemed to derive from different perceptions of practical buildability aspects. Because there was too little space for hiding properly all sockets etc. the appearance of some electric installations (e.g. ‘emergency exit’ signs and lights) ended up having more ‘clumsy’ appearance than preferred by the designers. The electrical engineer commented on this: “Architects who draw designs with plenty of floor-to-ceiling height are rewarded the benefit of aesthetically nice installations.”\textsuperscript{148}

5.4.9. Development of client/user expectation (expectation management)

The case study highlighted that some stakeholder expectations could develop in directions that complicated management and planning of design and production. One illustrative example concerned the possibility of dividing the living room of the standard housing-unit into two, where a minor miscommunication between architects

\textsuperscript{146} Discussed above.
\textsuperscript{147} Since the floor-to-ceiling heights were close to the very minimum possible it was in general not possible to adjust the design by adding to the dimensions of the floors.
\textsuperscript{148} Design committee meeting, November 11\textsuperscript{th} 2004.
and some user representatives gave rise to a series of expectations regarding the individual housing unit and design decision processes:

At an early stage of the project a representative of Architects A participated in a meeting with the user’s committee where he expressed that the architects considered the possibility of enabling a division of the residents’ living rooms with an optional light partition wall. This feature was not included in the programme and the retrospective view of the architect who coordinated the work of the users’ committee was that that he had merely informed the user representatives about some of the ideas and considerations that the architects were having while developing the design. No promises had been given. Nevertheless, expectations somehow developed among stakeholders on the client-side and soon it appeared that users in general were under the expectation that partition walls would be an option that the individual tenant could have added to the project. This expectation was problematic since the conceptual design ended with the result that an extra partition wall would be inappropriate since a division would result in rooms inappropriately small. Furthermore, the fire regulations would demand a design change regarding the living room windows specified if the living room could be divided into two separate rooms. Already in September 2004 the design committee concluded that possibilities for adding partition walls should be left out. This, however, left the design committee with a problem since the final design was supposed to be approved by the users who unfortunately expected that they could divide the room if they pleased. It was decided to build a mock-up of the housing unit. The mock-up was expected to support users’ feedback on details of interior design and to help them prepare for taking the facility into use. It was also seen as a valuable tool for illustrating to users that partition walls would not work well in practice. The representative of Architects A was very concerned about the matter of the partition walls because some users had also started talking about separating the room with a bookcase. A solution that would take even more space than would a partition wall. There were clear signs of user expectations having developed into unreality. Users’ feedback and approval was critical because the design progress was dependent on final design approval by the client who, given the organisational circumstances, was considered very unlikely to approve a design disregarded by the users’ committee.

Clarification on the matter of partition walls was critical for a number of reasons. The contractor needed to order windows for the living rooms (where legal requirements regarding the windows used were dependent on whether the room could be divided or not). Another reason was that the contractor had planned the assembly process so that windows would be installed immediately after the erection of the walls and roofs. This way temporary wood/plastic

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149 Design committee meeting, September 30th 2004.
150 The architect who coordinated the work of the users’ committee had many years of experience from working with users, and he believed that the reason for the apparent enthusiasm for partition walls was that many users had an insufficient understanding of the actual size of the housing units that they had hitherto only seen on drawings.
151 The mock-up had already been proposed by the municipality’s office for social affairs since the staff of the pensioners’ centre had asked for it. (Project meeting, September 29th 2004).
frames and covers could be avoided. Avoiding temporary frames would save work operations, materials and a high quantum of energy for heating the facilities during the winter period when the interior works were to be executed and the concrete structures dried.

The issue was brought forward at a project meeting in late October 2004.\textsuperscript{152} Architects A and the DB-contractor expected that a formal acceptance could be obtained at this meeting since it was their impression that they had previously been informed that client decisions were to be carried by October 25\textsuperscript{th} (in which case design could proceed according to their plan, given that the users’ committee had not disregarded the design proposal). At project meetings the municipality was represented through an official from the social affairs administration (which \textit{de facto} was a key power-holder in a strong position to influence the client and its position). The official reported that the members of the municipality’s social affairs committee expected that they would be the ones carrying final decisions regarding design approvals and that the matter had already been scheduled for a meeting on November 25\textsuperscript{th}. To the contractor this was highly problematic and an important economic factor. The municipality official emphasised that local politicians now expected that each housing unit could be divided into two and that the politicians themselves were the ones who should carry the final decisions if such design parameters were to be changed. He stated that the politicians would become very upset if discovering that prior to the meeting of the social affairs’ committee a decision had already been carried at the level of the municipality officials.\textsuperscript{153} He was therefore not willing to accept that a decision could be carried on the project level prior to the meeting of the municipality’s social affairs’ committee. Architects A and the client’s project consultant insisted that the question was a matter to be dealt with on project level (by the users’ committee) which they expected would become convinced when the user representatives saw the mock-up (which should be ready within few days when the users’ committee was to inspect it). The parties could not reach agreement and the meeting concluded with deciding that the client’s project consultant would follow up on this issue together with the client organisation. Thus the contractor was still without formal clarification when passing the ‘last responsible moment’ for deciding on the most efficient assembly strategy and window selection without risking negative cost/time/process consequences.

\textsuperscript{152} Project meeting, October 27\textsuperscript{th} 2004.

\textsuperscript{153} The issue of satisfying the municipality’s political representation was considered vital by all parties involved in the project. The project was subject to some attention in the local community and the pensioners’ centre was scheduled for opening shortly before upcoming local elections. On this background it was important to the client organisation and the project delivery team to secure as much political goodwill as possible. Just how important this was considered to be was illustrated by the practical arrangements for the cutting of the first turf. The client organisation imagined that the local mayor would appreciate that the press at this occasion got some good pictures of him in front of a heavy excavator (symbolising activity and local development). Though such machinery would not yet be needed on site the contractor was asked by the client to arrange for an excavator to be present. For the price of about DKK 10,000 (€1,400) and a full day’s work of the production manager, the biggest excavator available was transported to the site for the turf-cutting ceremony and was removed immediately after. (Eventually, on the day of the ceremony it was rainy why the mayor was anyway not interested in posing in front of the excavator).
5.4.10. Differences in perception of importance of certain issues

As it has also been illustrated in some of the themes discussed above, project participants and stakeholders were often having somewhat different perceptions of the importance of certain project issues. In some instances this provided problems since it was difficult for the parties to plan and prioritise their efforts without a clear picture of the internal ranking of value parameters. One example concerned prolongation of the deadline for commission and handover of the first project phase. Due to the many troubles regarding redesign, approval processes etc. the contractor’s production manager found it would be advantageous and fair if he could get a prolongation of the deadline. At a project meeting with other stakeholders (including representatives of the municipality) this wish was, without prior warning, brought up in front of the client’s project consultant who evidently became very displeased. It was subsequently discussed in the design committee that the situation had been inelegantly handled by the DB-contractor. The production manager straightforwardly admitted his mistake. He had not been aware that his proposal was as controversial as it appeared to be. It had already been discussed among the designers that it seemed that the first occupants would move in later than what had been assumed in the original schedule. A little informal research suggested that the (formal) client organisation risked extensive day fines if the project would not be ready for use as according to the contract with the municipality. Such information was otherwise kept firmly under wraps by the client and its project consultant. (This episode was one of the events prompting that the client’s project consultant and the DB-contractor agreed to enhance their communication, and it was later approved that the first phase could be handed over one month later than according to the original schedule).

Difficulties deriving from different perceptions regarding the importance of certain issues were not limited to the interaction between construction professionals and laymen, but were also experienced between the professionals. Most examples concerned the importance of certain information being available at specific design stages. Usually this was at some point discovered during discussions of the design committee meetings, and often with some implications for planning of other tasks/assignments, and a need to renegotiate with suppliers about new and shorter notice for specifications regarding specific elements, modules etc.

One example of a very simple and straightforward, but nevertheless critical, issue where a ‘near miss’ could have provided considerable trouble, concerned the assembly of the living room mock-up. As discussed above, the design progress became challenged when some users got the false impression that they could take for granted that the living room in each of the 112 rehab units could be divided by a light wall. From experience members of the design committee knew that such expectations, if disappointed, could cause considerable conflict and problems in the project, and it was decided to prioritise the construction of a mock-up of a living room (discussed above). It was expected that this could a) help Architects A make the user groups realise that a division of the room would in fact be very inappropriate, and b) that a

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154 His initial reaction was to declare a 5 minute break and leave the room to make a phone call. (Project meeting, October 27\textsuperscript{th} 2004).
155 As mentioned above, the Last Planner System was not particularly thoroughly applied and especially the look-ahead planning (see Ballard 2000a) was not systematically conducted with structured discussions at committee meetings.
mock-up would be valuable to users who could use it for obtaining a better image of their future home and to prepare for taking it into use. Since clarification regarding possible partition walls was urgent (and critical for the ordering of the right windows unless giving up on the assembly strategy) it was necessary to have the mock-up ready for demonstration for an upcoming scheduled meeting of the user committee. With short notice it was arranged that the mock-up could be built in an empty room of a local public building and (without the DB-contractor having inspected this room) a local carpentry contractor was hired to build the mock-up. What happened next was that the DB-contractor’s production manager was called by the carpentry firm who, when just about to start assembling the mock-up, found that it would inform the DB-contractor that some modifications would need to be made. Due to the dimensions of the surrounding room the mock-up would be 0.5m narrower than specified on the drawings. The production manager ordered the work to be stopped immediately, and he later reported at a design committee meeting\(^{156}\) that it was pure luck that he had been able to answer the phone when the carpenter called. The carpenter had admitted that he did not realise the importance of the mock-up actually being of the right dimensions and he would therefore have continued the work had he not spoken to the production manager.

(Eventually arrangements for a new location for a 1:1 mock-up were made. With extremely short notice an alternative location was found, thanks to help from the client’s engineering consultant whose local connections saved the situation).

5.4.11. Facilitation

Observations indicated that facilitation was an important issue in relation to a large number of situations regarding cooperation, negotiation, dispute resolution, management, stakeholder involvement etc. Only in relation to the Architects A’s involvement with coordinating the work of user groups was facilitation explicitly discussed, but it was nevertheless obvious that facilitation played an important role in relation to many other project processes.

Examples of facilitation processes taking place at different organisational levels were:

- **Design committee**: Despite that the project suffered some problems of progress and coordination and in spite of considerable dissatisfaction among some project participants, the design committee worked with a high degree of consensus and in a collaborative atmosphere. It was obvious that the design manager paid much attention to processes of communication and collaboration in the design committee. Dependent on the topic being discussed, other participants occasionally took on a role of facilitator, though this was never stated explicitly.

  During the project there were some examples of disagreement, and occasionally regular disputes, concerning specific issues. However, it appeared that the members of the design committee were all very determined that problems and challenges should be worked out collaboratively and, if at all possible, by consensus. Though at some stages the project appeared to be relatively conflict-ridden at a number of organisational levels, the design committee managed to avoid conflicts from escalating among the designers. One reason for this might have been that the design manager appeared to be very careful that conflicts were kept out of the design committee forum. When

\(^{156}\) Design committee meeting, October 6\(^{th}\) 2004.
5. Case II: Rehab-housing units in Denmark

occasionally it became clear that an issue could not be resolved in the design committee, it was typically decided to seek a solution outside this forum (commonly with involvement from other organisational levels of the project or of the organisations participating).

- **Users’ committee**: No activities of the users’ committee were attended during this research, but in discussions of the design committee, facilitation was often mentioned as being crucial for ensuring sufficient communication with and among the different user groups and to guide the highly diverse stakeholder group (that mainly consisted of laymen without professional experience of construction) through identifying their actual needs, wishes and project delivery value. From discussions in the design committee there seemed to be a common understanding of such tasks as being very challenging, and the representative from Architects A (who also functioned as coordinator of the users’ committee) expressed that facilitating the communication, cooperation and negotiation processes related to achieving sufficient user input, feedback and support required a lot of work and effort. Expectation management was considered a key issue in this respect. In some examples failure to manage stakeholder expectations provided significant difficulty to the design and project management, e.g. in the example of whether or not apartment living rooms would/should be dividable with light partition walls (see above).

- **Project meetings and steering committee meetings**: These meetings were chaired by the client’s project consultant who, during the meetings observed, also acted as a very active facilitator. During these meetings the client consultant took clear leadership, and obviously sought solutions that would satisfy both the formal client organisation and the municipality. Though he occasionally had some controversies with the DB-contractor he insisted on solutions that as far as possible would also be satisfactory to the DB-contractor (who did not participate in the steering group meetings). He was obviously concerned to keep the project on a course where conflicts did not escalate beyond the manageable, where he could negotiate solutions and have the trust of all parties, and where hard success parameters of budget and schedule would not be compromised.

**Other meetings and project processes**: The project was widely fragmented regarding decision and communication processes. It seemed that different project participants actively sought to facilitate communication and project processes on the interface between different organisational levels and units. In addition to the facilitation discussed above, another example of facilitation that appeared to be of significant importance during the project was: One representative of Architects A (who coordinated the work of the users’ committee) was a very active facilitator in a number of discussions in the design committee but also in other meetings where it appeared that he, often with a great deal of diplomacy, brought a deadlocked discussion forward by formulating very precisely: the core problem; the core aspects of disagreement; the (in his perception) core project value aspects in relation to the specific situation; the extent to which consensus existed, and; a proposal for a new angle from where to work towards solution and agreement.
This architect was (as the only person) represented in the meetings of all key project committees, and at various meetings he was often very active trying to support other project participants in understanding the situation from the positions of those parties not present.

5.5. Summary of findings
The case study illustrated an example of how difficult it can be to pursue design/construction integration if contradicted by the contextual and organisational setup of the project. The findings will be further discussed in Chapter 7. The case highlighted how political processes and organisational turbulence can in some instances prevent a lean approach for systematically enhancing value delivery and addressing waste. In relation to lean application, the case clearly illustrated how the absence of a clear and shared picture of stakeholders’ and participants’ value parameters is a crucial precondition. Lean elements and integration indicators from the case will be summarised in the following:

5.5.1. Lean elements
An overview of the case findings regarding lean elements is provided below (Table 5.1):
<table>
<thead>
<tr>
<th>Lean design/construction element</th>
<th>Present in majority of processes</th>
<th>Present in some aspects</th>
<th>Not present at all</th>
<th>Contradictory</th>
</tr>
</thead>
<tbody>
<tr>
<td>Focus on optimising value for client and users</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Value stream mapping</td>
<td>●</td>
<td></td>
<td>●</td>
<td></td>
</tr>
<tr>
<td>Value unambiguously interpreted in relation to end customer</td>
<td>●</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Waste reduction focus</td>
<td>●</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Approach value and waste from a system’s perspective</td>
<td>●</td>
<td></td>
<td></td>
<td>●</td>
</tr>
<tr>
<td>Perfection aspiration</td>
<td>●</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Systematic experimentation</td>
<td>●</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Strategy for building continuous improvement into the process</td>
<td>●</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Strategy for making improvements permanent</td>
<td>●</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Strategy for strengthening learning and inter-organisational team learning</td>
<td>●</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Early supplier involvement in design</td>
<td>●</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Systematic reduction of variability</td>
<td>●</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Concurrent design of product and production process</td>
<td>(●)</td>
<td></td>
<td></td>
<td>157</td>
</tr>
<tr>
<td>Production control on the entire design/construction process</td>
<td>(●)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Simplify organisation</td>
<td>●</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Effective client involvement in design</td>
<td>●</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Set-based design process</td>
<td>●</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Process transparency in design</td>
<td>●</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Process transparency in production</td>
<td>●</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Measures to systematically enhance SC collaboration</td>
<td>●</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>‘Pull approach’ to design</td>
<td>(●)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>‘Pull approach’ to production</td>
<td>●</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Long-lasting supply chain relations</td>
<td>●</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cost reduction targets</td>
<td>●</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Securing of continuous work flow</td>
<td>●</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Levelling workload</td>
<td>(●)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Last Planner System</td>
<td>●</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SS 158</td>
<td>●</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Just-in-time (JIT) logistics</td>
<td>(●)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Defect-detecting system (‘poke yoke’)</td>
<td>●</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Systematic approach to stress system for identifying weaknesses</td>
<td>●</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 5.1: Overview of the case findings in the perspective of widely common elements of lean application.

157 The design committee pursued a concurrent approach, but often failed due to uncertainty, project changes, and decision and approval processes that were out of sequence with the design progress. In any case, given that the delivery team worked according to a fixed conceptual design, only details could be designed concurrently with production processes.

158 “5S” expresses five simple and popular principles often applied in lean manufacturing as good shop-floor practice. 5S is short for Sort, Set in order, Shine, Standardize, and Sustain.
5.5.2. Integration indicators

As was discussed in Chapter 3, Baiden et al. (2006) describe a delivery team in a construction project as ‘fully integrated’ when it satisfies the criteria of Table 5.2. From this understanding of integration it is possible to summarise the case studies as follows:

<table>
<thead>
<tr>
<th>Project indicators of integration:</th>
<th>Present in majority of processes</th>
<th>Present in some aspects</th>
<th>Not present at all</th>
<th>Contradictory</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project delivery team with a single focus and objectives for the project</td>
<td></td>
<td>●</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Project delivery team operating without boundaries among the various organisation members</td>
<td></td>
<td>●</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Project delivery team working towards mutually beneficial outcomes by ensuring that all the members support each other and achievements are shared throughout the team</td>
<td></td>
<td>●</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Project delivery team able to predict more accurately, time and cost estimates by fully utilising the collective skills and expertise of all parties</td>
<td></td>
<td>●</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Project delivery team sharing information freely among its members such that access is not restricted to specific professions and organisational units within the team</td>
<td>●(^{159})</td>
<td></td>
<td>●</td>
<td></td>
</tr>
<tr>
<td>Project delivery team with a flexible member composition and therefore able to respond to change over the duration of the project</td>
<td></td>
<td>●</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A co-located project delivery team with a new identity</td>
<td></td>
<td>●</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Project delivery team offering its members equal opportunities to contribute to the delivery process</td>
<td></td>
<td>●</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Project delivery team operating in an atmosphere where relationships are equitable and members are respected</td>
<td></td>
<td>●</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Project delivery team with a “no blame” culture</td>
<td></td>
<td>●</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 5.2: Overview of the case findings in relation to indicators/factors of integration as identified by Baiden et al. (2006).

\(^{159}\) This was largely the case for the collaboration between the members of the design committee, but not from the perspective of the overall project.
6. Case III: Extension of a medical care centre in California

This case study introduces the early design and building activities of a part of a major extension to an existing medical centre in California. The project was studied over a period of three months around the turn of the year 2004/2005 and in the autumn 2005. During the period studied schematic and detailed design was being developed along with the early stages of the site work. The data collection for this study was finished when 50% of the construction documents were completed.

This case study describes a client-driven approach to an integrated implementation of lean design and lean construction methods throughout all phases of the delivery of a modern medical care centre facility. On this project the design/construction integration theme was tackled mainly from the perspective of enhancing client and user value while staying in control of cost development.

This case study is primarily focused on value definition processes, collaborative design, and on the experiment of enhancing value delivery through the application of principles of ‘designing to target cost’.

6.1. Case description

The construction project studied was to provide the client with a new facility - an acute rehabilitation centre (ARC) - as an extension to an existing hospital and medical centre. The project studied was one of several projects that were to enlarge the capacity of the existing medical centre. This medical centre needed to expand the capacity for several of its existing services and also take over several functions from another local hospital. The decisions to undertake these extension projects had evolved over a period of time and were driven by a large number of processes, mechanisms and factors (internal as well as external) of which many were interconnected in multiple ways. At several levels political processes concerning the development of the region with its infrastructure and facilities, including the public healthcare facilities, had influenced the course of development where unpredicted demands, wishes and needs gradually avalanched into a number of individual decisions for separate extension and expansion projects/sub-projects for the medical centre.

As a consequence of these fragmented processes no overall approach to the entire facility extension had been possible prior to the development of the individual (sub)projects.

The total budget for the new acute rehabilitation/vent department was US$58,572,000 of which two thirds were construction costs and one third furniture and equipment. Contingencies amounted to $9.4 million or 16% of the total budget. The project was based on a feasibility study and was scheduled to commence with schematic design in September 2004. Construction documents were to be submitted for approval at the end of 2005. The construction period was scheduled to last for 18 months between March 2007 and September 2008.

Shortly after the project was incepted it was decided that it should be executed through an integrated approach to design and production managed through principles, tools and methods known from the lean construction movement. While the key project participants – client, architect and contractor – all had some experience with
collaborative design activities and different lean construction approaches to site-work, this project would be their first attempt of implementing the Last Planner System\textsuperscript{160} to the management of design processes. It would also be their first experiment with applying a \textit{design to target cost}\textsuperscript{161} methodology for the benefit of client value and cost management, and to minimise the number of necessary design iterations. All parties viewed this project and the ongoing implementation process as an experiment that was expected to provide the parties with insight, knowledge and know-how applicable for future activities.

6.1.1. About the key participants
The project participants most central in this case study were the client, the architectural firm and the general contractor:

- **The client** is a large non-profit network of hospitals, medical clinics and other providers of healthcare services. The client’s activities include the operation and management of buildings, campuses and other real estate facilities of the health care providers within the network. Many of the facilities requested by the client are on a technically very advanced level demanding a collaborative approach between specialists in many fields. In the period from 2004-2012 the client expected to procure new facilities for approximately $7.5 billion in order to expand capacity and replace some older facilities. In 2003/2004 the client adopted a procurement strategy based on a lean construction philosophy of collaborative working and an integrated approach to value delivery (see below). Lean design/construction tools and principles were under implementation as this case study was started. The client believes that collaborative working is a way through which it can achieve more direct influence/control on the value delivery process than what would be possible through more indirect project management strategies. The client has an internal central department for facility planning and development where about 50 construction project managers and additional support functions are responsible for the realisation of the organisation’s many construction projects.

- **The architectural firm** is a large provider of building design services with several offices in California and in a few other states in the USA. One of the company’s three main business areas in Northern California is designing health care facilities, mainly for the client behind the project studied here. In addition to this project the company also provided the architectural design for other extension projects on the same hospital campus. All in all, the company’s extension projects on this campus accumulated above $100 million in construction budget. On the health care projects, such as the one studied, the architectural firm usually directs all design activities from the earliest briefing phases to the projects completion. As a part of the firm’s philosophy of working, its architects seek to involve the contractors and central subcontractors extensively already during the development of the schematic design in order to

\textsuperscript{160} See Chapter 3, or (Ballard 2000a).

\textsuperscript{161} For an introduction to principles of designing to target cost, see (Jørgensen 2005).
develop solutions that can and will be successfully executed with respect to
design intent and within budget.

- **The general contractor** is a local middle-sized building company in Northern
  California. The contractor has specialised in managing the building of health
care facilities. Hitherto this business segment has generated more than half of
the company’s annual turnover of what (prior to the project of this case study)
had been approximately $50 million. The majority of the activities within this
field are jobs for the same hospital network which was the client behind this
case project. The company does not operate with in-house subcontractors but
concentrates on the planning and management of construction activities.
In the 1980s the contractor gave up competitive tendering and pursued a
strategy of working collaboratively with selected suppliers, typically with a
high degree of continuity over time. The company sees the collaborative
approach as an absolute prerequisite for enabling successful performance
(including client satisfaction) at its health care projects that are highly
technically and organisationally complex. Over 80% of the contractor’s work
is for repeat customers.

### 6.1.2. Background

The client, architect and contractor had many years of experience in working together.
The client’s choice of architect and contractor was based on the expectation that these
companies were qualified for the job and that there was potential for further
developing of the collaborative relations with these suppliers. Hitherto the general
contractor had not taken on high-volume work to the extent of the ARC (here studied)
and other parallel projects on the campus and these projects would require some
expansion of the company. This had been a concern to the client who nevertheless
assessed and trusted that the contractor (who had a very good record with the client)
would manage successfully. The client believed that the high volume of work
awarded this contractor should also be perceived as activities for developing its
supply chain.\(^{162}\)

Three of the parallel extension projects on campus had the same client project
manager, chief architect and contractor project manager. In addition to the acute
rehabilitation centre (ARC) the other two projects were the so-called bed tower, which
primary function was to provide bed capacity for patients, and a neonatal department
that included a nursery. In addition there were two simultaneous (and technically
interrelated) projects right next to the ARC: a major extension of the existing
emergency department, and; the construction of an entirely new parking structure with
two helipads on the roof. The parking structure was executed with different
contractors under a design-build framework.
The three companies’ individual project managers also had some experience of
working together. The chief architect and the contractor’s project manager had
previously worked together at several projects. Prior to this project the chief architect
and the client’s senior project manager had worked together on a single project (for a
different client) which was during the senior project manager’s previous career in a
contractor’s organisation.

\(^{162}\) Conversation with client’s senior project manager, October 6\(^{th}\) 2005.
6.1.3. Specific project challenges

The client’s project manager, the general contractor’s project manager and the chief architect all found that designing and building health care facilities had challenges particular to this category of construction projects: a large number of different stakeholders, high technical complexity, rigid public regulation and lengthy complicated approval processes were mentioned as examples of issues generally complicating the design, construction and project management when building health care facilities. There were a number of aspects specific to the project studied that demanded special attention from the very beginning of design and planning:

- **Existing facilities not designed for extension:** Though planned only 12 years before the time of the case study, and taken into use as late as 1997, the medical centre already needed major up-grading of capacity and functions. Unfortunately the existing facilities had not been designed for future extensions. This caused several challenges, architectural as well as technical and organisational, since most of the existing facilities needed to be functioning throughout the project period (see below).

- **State-of-the-art project with no previous cases:** The ARC (including the building itself) was to function with the latest technology. It was a state-of-the-art facility for which there was no previous cases to provide experience and guidance.\(^{163}\)

- **Parallel extension projects:** As mentioned above, several projects for the same campus were scheduled for parallel or overlapping construction periods. This situation was demanding in respect to the coordination between the work-scheduling of different project activities and the coordination and information-sharing among contractors and suppliers during site work. The project managers representing the client, architect and general contractor all expressed that they found it unfortunate that the different extension works had been split between so many different projects and contractors.\(^{164}\) These arrangements followed some earlier decisions in which none of them had been personally involved.

- **Continuous function of existing facilities:** Major parts of the existing facilities needed to be kept continuously functioning throughout the period of the expansion projects. Operations of the medical centre had many inter-connected functions and several physical facilities served many different units of the campus. This naturally complicated planning and execution of construction processes. An example of an issue critical to the construction of the new ARC facility was its connection with the neighbouring emergency department, which was under simultaneous expansion. An analysis had revealed the minimum capacity necessary for the emergency department to remain in function throughout the project period. Under no circumstances should the emergency department need to compromise a minimum capacity of 16 beds (of a total capacity of 40). The need for securing constant possibility

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\(^{163}\) Statement by chief architect, group interview, November 15\(^{th}\) 2004.

\(^{164}\) Group interview with the client’s senior project manager, the chief architect and general contractor’s project manager, November 15\(^{th}\) 2004.
for fast and efficient transportation of patients and equipment within the emergency department forced project management and all parties working on the expansion to plan and execute most work activities with the utmost care. Additionally the work needed to be very well structured in order to limit the general disturbance to users (not least the patients) as much as possible. The requirements regarding the continuous function of the emergency department also provided several constraints to the construction of the new acute rehabilitation centre. The ARC was to be erected where the existing heliport was situated. Two new helipads were to be built on top of a new parking structure that was under construction as part of another project on the site - but until this new heliport could be taken into use the existing would need to be operating more or less as normal. To enable this, a sealed corridor was built across the construction site from the helipad to the emergency department. For safety reasons, and to keep the helipad operating with as little disturbance as possible, all site work would immediately be stopped whenever a helicopter was about to arrive. This required fast and efficient communication at any given time on the entire site. Likewise it was necessary at all times to maintain fast access for ambulances to the emergency department. The existing ambulance gateway would be removed to make space for the new ARC and thus all ambulances would need to use the main gateway to the medical centre throughout the construction period. As it was vital to provide ambulances possibilities for fast access and exit at any time, this made the coordination of all incoming traffic a critical factor. Thus the ensuring of coordinated deliveries to the construction site was a highly prioritised demand. In general there was relatively little space available for the construction site and the execution of the building processes. Under these circumstances the management of site logistics was extraordinarily difficult. Having several projects under parallel construction right next to one another (and dependent on the same access roads/streets) made the site management a constant challenge.

6.2. The project organisation
The project was organised as a design-assist project and structured around a steering committee consisting of 15 members representing different parts of the client organisation, the general contractor and the architect. These client-side members of the steering committee represented the client’s internal department for facility planning and development, the top management of the medical centre, the management of the ARC function and the staff that was to work there. The steering committee was responsible for dealing with fundamental project decisions and it was composed to ensure representation of the interests of both the health-care network at large and of the local affiliate and users.

6.3. Project delivery strategy
The applied project delivery strategy could be described as consisting of two levels:
   a) The client’s general ‘lean’ project philosophy which the organisation had formulated in what was called “The Five Big Ideas”.
   b) Project specific initiatives that were to support project delivery in accordance with this philosophy.
6.3.1. “The Five Big Ideas”

The client organisation’s commercial strategy was formulated in the so-called ‘Five Big Ideas’ meant to communicate the lean initiative through which the organisation was seeking to improve value delivery at its construction projects. These ideas were:

- “Collaborate; really collaborate
- Projects as networks of commitment
- Tightly couple learning with action
- Optimize the whole
- Increase relatedness”

‘The Five Big Ideas’ were seen as interrelated and were, through their combination, intended to serve to enhance innovation, competitiveness, reliability, establishing of trust-based relationships and the achievement of continuous improvement. The strategy was usually illustrated through this representation:

![Figure 6.1: “The Five Big Ideas”. (- From internal material of the client organisation).](image)

It is important to notice that this strategy was not aimed only at construction delivery per se but was based on a perception of construction projects as constituting a support activity for providing health care services. Thus the ‘Five Big Ideas’ expressed a philosophy through which the individual construction project was to be managed in respect to the underlying objectives of the client organisation. In other words, it was a strategy aiming at enhancing coherence between the perspectives of the individual construction project activity and the activities of the client organisation.

The development and formulation of the strategy represented by the ‘Five Big Ideas’ was to a large extent prompted by the need to ensure a successful execution of the
multi-billion dollar programme, which in the case of failure would carry serious consequences for the client organisation. Other aims were to improve the patient experience and the general quality of the health care services provided, to sustain operating margins for investment, to minimise financial risk of construction projects, and provide real-time project reporting to a variety of groups. An explicit objective was also the need to achieve the smoothest possible approval processes in relation to the Office of Statewide Health Planning and Development (OSHPD), the public authority in charge of the Californian healthcare sector. The OSHPD approval process is considered to be very rigid and an obstacle to fast and efficient project delivery. Pressure for increasing the reliability of ‘long lifecycle projects’ (5+ years duration) in terms of budget, schedules, claims etc. provided additional motivation behind the client’s development initiative, and also HR issues (such as work safety and the avoidance of staff burn-out) was an important motivation.

6.3.1.1. The introduction of a lean strategy

The client, who almost always led its own projects, had for some time been working with implementing lean construction tools and principles on the construction sites of its projects. With extensive support from recognised lean construction consultants the client had focussed on making the Last Planner System (LPS) (see Ballard 2000a) an established procedure for the scheduling of site work, while seeking to simultaneously change inter-firm cooperation and task/operations management from the traditional ‘command and control’ approach to a collaborative approach of a ‘network of commitments’ (as described by Macomber & Howell (2003), a publication that had inspired the client for its chosen strategy for inter-firm cooperation). The collaborative approach was the cornerstone of the client’s philosophy for obtaining more satisfying construction procurement and was also the main pillar of its lean construction implementation strategy. The client found that a collaborative approach and management through networks of commitment were a necessity for successful value-delivery at the technically complicated facilities it procured. From this point of view the client had identified the lean construction philosophy as providing the best available tools and principles to match its needs and views on construction project delivery. For the practical implementation throughout the client’s project portfolio a few experienced construction managers, who were found to possess the right skills and attitudes, had been headhunted to work for the client organisation. Potential candidates had been few, as most construction managers were very sceptical to this way of working.165

It was a deliberate decision by the management of the client organisation to provide these individual change agents a lot of room to choose individual implementation strategies according to circumstances on the different projects. Project managers and others were encouraged to share their experiences and openly communicate difficulties they faced during the implementation efforts (discussed below).

6.3.1.2. Themes

The lean initiative was built around four themes that the client and its consultants had identified as the basis for a holistic approach to the organisation’s lean implementation:

- physics of work;

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165 Conversation with the client’s senior project manager (and later lean coordinator), November 11th 2004.
6. Case III: Extension of a medical care centre in California

- design of systems;
- organisation, and;
- contracts.

The client took a multi-project approach to lean construction in the sense that measures taken centrally were to support the entire project portfolio. Initiatives were taken from the perspective of achieving improvements over the long term, not expecting them all to pay off already on the initial pilot projects. This is best illustrated in the most long-standing long-term initiative taken: the work on developing new contractual relations supporting the lean approach. The client saw the realisation of its efforts of embracing the lean construction philosophy as being heavily dependent on successfully establishing/developing stable and collaborative inter-firm relationships within the supply chain. The client pursued strong partnering relations on project and company levels but found conventional legal contracts insufficient as a basis for cooperation according to the lean philosophy and “The Five Big Ideas”. Previous standard contracts were perceived as something that did not support process-orientated procedures nor promote collaborative efforts for value delivery. The client therefore took up the challenge of developing contractual practices in line with the overall lean strategy. This was recognised as something which constituted a major challenge and a required a lengthy process to carry through. The work was done in close cooperation with a specialised law firm and was expected to last for several years of development and implementation. In the beginning of the strategy implementation the organisation put relatively little emphasis on individual tools, but demanded from its project managers that they ‘embraced the ideas’ of the strategy. Project managers were provided much room and freedom to decide on the actual implementation strategies and the use of tools for each individual project. In the official policy the project managers were encouraged to discuss their work and results (successes and failures) and express any criticism they happened to have regarding the application of lean construction. This feedback and discussion was perceived vital to the organisational learning and to the conceptual development of the lean construction initiative.

6.3.2. Project specific initiatives

Parallel to the development of the general strategy formulated in the ‘Five Big Ideas’ a number of potential lean construction tools were identified but no concrete procedures for their application prescribed. For the ARC project studied the project management decided to invest considerable effort in implementing two procedures that the client organisation had identified as measures highly relevant for further examination and experimentation:

- ‘Design to target cost’ (named “Target Value Design” in the client’s lean concept), and;
- The Last Planner System (LPS) in design and production.

It was the expectation that testing on pilot projects would serve as preparation for further systematic adoption within the client’s construction organisation and its pool of suppliers.

The ARC project was the first attempt to apply ‘design to target cost’ procedures on a wider project level. The client organisation named its target costing approach ‘Target Value Design’, emphasising that it was aimed not only at driving down costs first and
foremost to ensure that the value pursued would in fact be delivered, and also within a feasible economic frame. The Last Planner System had been applied on an experimental basis for the production phases on some of the clients’ projects. Applying the method for design management was new to the participants of the case project. The decision to use the LPS already in design was based on the aim to support structuring the comprehensive design and cost-feedback process.

6.4. Design to target cost

Methods of target costing adopts a feed-forward perspective to cost management where the fundamental objective is to design costs out of the product instead of cutting costs out of a design after this has been found to be too expensive. Target costing addresses relationships between product design and costs already during early stages of design/product development where the scope for cost reduction is bigger than if needing to search for ways to reduce costs from a finished design or during production. Essentially costs thus form an input to the design process instead of merely being an output of it. An integral part of this approach is the application of value engineering techniques to identify initiatives that can decrease production costs while maintaining the functionality and quality demanded by the customers (Cooper & Slagmulder 1997; 1999; 2004).

The client’s new initiative for ‘design to target cost’ differed radically from the organisation’s previous practices since it included a feasibility study that formed the basis for setting the target cost. This is illustrated in the following two process diagrams which the client used to explain the change in procedures:

![Figure 6.2: The client’s standard project procedure with the feasibility study added (figure from internal material of the client organisation).](image)

![Figure 6.3: The main project steps of preparing a feasibility study and establishing the target cost (figure from internal material of the client organisation).](image)

Under the new procedures cost targets were established subsequent to a feasibility study in concurrency with the project brief and early phases of schematic design. This method relied heavily on proactive involvement of subcontractors and other suppliers already from the earliest design phases. Suppliers were made part of an extended design team where they frequently generated new cost estimates and gathered with
designers and other suppliers to discuss cost development and – when necessary - help develop alternative design solutions that could bring savings without violating the design intent.

The inspiration for adopting the method had evolved between the contractor’s project manager and the client’s senior project manager (responsible for the ARC and other projects on the same campus). Realising that cost-development could be very challenging on the project they discussed how to manage the process. They both found traditional - ‘design first, estimate after’ - approaches to be insufficient for effective project management and satisfactory value delivery, and they concluded that there had to be a better way. They agreed that better cost-estimating feedback could be obtained through intense supplier involvement throughout the design phases. This was brought up with the client’s external lean construction consultants who told that such a method already existed and was under implementation by a large contractor in Wisconsin.\textsuperscript{166} As a starting point the approach taken by this contractor was adopted for application for the ARC project that was to generate some of the client’s first experiences with target costing.\textsuperscript{167}

It was decided to conduct a feasibility study for establishing a firm basis for defining needs, value parameters etc. and support the setting of cost targets. The steps and main processes of the feasibility study were later mapped by key project participants, (see Figure 6.4).

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\textsuperscript{166} Some experiences from this initiative have been reported by Ballard & Reiser (2004).

\textsuperscript{167} For a more detailed discussion of ‘design to target cost’ in construction, see (Jørgensen 2005).
6.5. The Last Planner System

For a few years the client’s department for facility planning and development services had occasionally applied the Last Planner System (LPS) (Ballard 2000a) to the production phases of some large projects. More than as a procedure for work planning this method was primarily adopted from the perspective of enhancing communication among suppliers. As part of the efforts of developing a more integrated supply chain, the client was now to conduct experiments with applying the LPS to the design phases where it was expected to complement the target costing and value engineering exercises through improved task coordination. At the project studied the client, architects and general contractor were all to gain their first experiences with the LPS techniques in the planning and scheduling of the design processes.

6.6. Findings from the target value design process

From the studies of the ARC project (and the occasional visit to some of the parallel projects on the campus) observations revealed a large number of issues and mechanisms that appeared to have been of some influence to the project’s course of development.

From the perspective of design/construction integration a number of findings will be discussed in the following:

6.6.1. Design developed in conformance with project budget

The design to target cost (‘Target Value Design’) procedure implied several relatively detailed cost estimates and reviews that provided important feedback on the preliminary design and served as input for the further design processes. The procedure required intense supplier involvement and many hours spent at target costing sessions where potential design solutions were discussed and cost consequences analysed.168 Throughout the design phase large amounts of cost data were generated (often to be made obsolete by later design revisions). For an example of how cost estimates developed as the design was produced and perpetually revised, see Table 6.1.

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168 ‘Target Value Design’ meetings were several hour-long sessions where key project participants were all present at the same location. The meetings were hectic and supplier representatives frequently left the meeting rooms (often the participants split in groups for parallel discussion of issues that were not interrelated) to make phone calls for achieving fast cost feedback on the ideas and new design proposals discussed. The outcome of the meetings was more than just improved cost information, and a large number of production processes and their coordination were collaboratively discussed and evaluated by the participants as a part of the process of assessing costs.
<table>
<thead>
<tr>
<th>Categories:</th>
<th>Target Costs 07/10/04</th>
<th>1st pass 10/25/04</th>
<th>2nd pass 11/02/04</th>
<th>Schematic design 12/12/04</th>
<th>Variance</th>
</tr>
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<td>1. General conditions</td>
<td>$2,599,402</td>
<td>$2,626,713</td>
<td>$2,552,631</td>
<td>$2,559,402</td>
<td>$0</td>
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<td>2. Site work</td>
<td>$1,158,105</td>
<td>$1,101,756</td>
<td>$1,783,364</td>
<td>$2,394,712</td>
<td>($1,236,607)</td>
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<tr>
<td>3. Concrete</td>
<td>$1,937,696</td>
<td>$1,288,832</td>
<td>$1,799,653</td>
<td>$1,399,182</td>
<td>$538,514</td>
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<td>4. Masonry</td>
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<td>$31,955</td>
<td>$420,280</td>
<td>$105,600</td>
<td>$156,116</td>
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<td>5. Metals</td>
<td>$2,664,750</td>
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<td>$3,357,752</td>
<td>$2,860,687</td>
<td>($195,937)</td>
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<tr>
<td>6. Wood &amp; plastics</td>
<td>$831,200</td>
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<td>$1,091,784</td>
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<td>7. Thermal</td>
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<td>$2,811,996</td>
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<td>$2,467,306</td>
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<tr>
<td>8. Doors and glazing</td>
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<td>$1,491,210</td>
<td>$1,664,560</td>
<td>$1,641,994</td>
<td>($249,050)</td>
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<tr>
<td>10. Specialties</td>
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<td>$803,123</td>
<td>$820,226</td>
<td>$815,533</td>
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<td>12. Furnishings</td>
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<td>13. Special Construction (pool)</td>
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<td>c. HVAC</td>
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<td>$194,604</td>
<td>$194,604</td>
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<td>e. Scrubbers on stacks</td>
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<td>$291,907</td>
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<td>$100,124</td>
<td>$97,302</td>
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<td>g. Mech. upgrade for Rehab</td>
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<td>$194,604</td>
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<td>16. Electrical</td>
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<td>$5,693,215</td>
<td>$5,040,370</td>
<td>($671,113)</td>
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<td>$645,481</td>
<td>$1,274,880</td>
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<td>$601,568</td>
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<tr>
<td>b. Connectio n Remodel</td>
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<td>$874,488</td>
<td>$680,000</td>
<td>$0</td>
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<td>$38,122,837</td>
<td>$39,158,293</td>
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<td>$1,494,351</td>
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<td>$1,189,059</td>
<td>$1,189,059</td>
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</tr>
<tr>
<td>Totals</td>
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<td>$44,291,164</td>
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<tr>
<td>S/sf</td>
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<td>$411,06</td>
<td>$420,90</td>
<td>$362,92</td>
<td></td>
</tr>
</tbody>
</table>

Table 6.1: Target budget comparison for the main construction activities (that were encompassed by the design to target cost initiative) and their development during the schematic design phase. Notice how some expensive features as the pool was given up during the process. Though above target after schematic design (where costs estimates had been conservative), project participants felt confident that they could identify the cost savings necessary during the design development phase. It was therefore decided to continue the project as according to schedule.
During design (schematic design and design development) the project participants managed to absorb a 10% increase in steel prices without the total cost estimate exceeding target. At this point the participants were optimistic regarding the possibilities of maintaining control over cost-development for the rest of the project delivery process. This was because the designers and suppliers found that the project was being unusually well worked-through (discussed below). An additional factor contributing to the optimism of the participants was that a possibility for further cost savings, related to the choice of water chilling capacity, was still being left open (discussed below). At the stage of 50% completion of the construction documents (in October 2005) the cost development regarding the project was still in line with the budget and the contingency budget remained almost intact. In January 2006, when completed design documents were submitted to the building authorities (OSHPD) for review, the project budget was still $58,720,000 (including almost full contingencies) which was identical with the target cost originally set.

6.6.2. Higher level of detail in early design phases
The early target costing exercises required that many details were developed to a level where reliable cost estimation was in fact possible. During design development (in February 2005) the chief architect and the project managers representing contractor and client concluded that the design had reached a level of detail similar to what was not usually reached before a project was well into the stage of design documents. More than half a year later (after 50% completion of construction documents), they concluded that this early investment had paid off through less negative iteration at later project stages.169

6.6.3. Sufficient feedback difficult to obtain
Throughout the design process it was often difficult to obtain the level of feedback that designers and project management found was necessary for the target value design process to function as intended. At a number of meetings the chief architect several times expressed some frustration about this and she called for more feedback. Especially feedback on written material, as e.g. minutes from meetings, was lacking.170

The client’s senior project manager often expressed dissatisfaction that too many suppliers failed to provide essential feedback at design stages when their inputs were crucial on order to avoid that the project would proceed with inappropriate design solutions. He found that he often experienced that suppliers only expressed their concern when they themselves wanted to benefit from consideration taken for misfortunate situations deriving from the way design had developed. The client’s project manager ascribed most of this problem to habit and he was optimistic regarding the possibilities for learning and improvement. He however pounced hard on project participants who in his opinion failed to engage in the process or who he suspected were trying to gain advantage from holding back information. The client’s project manager, and other central project participants, found that there had been a

169 Process mapping exercise and group interview, October 6th 2005.
170 Target costing meeting, January 26th 2005.
positive tendency throughout the project as participants gradually had become familiar with the new method.\footnote{Process mapping exercise and group interview, October 6\textsuperscript{th} 2005.}

On the users’ side it had also been difficult to obtain feedback on the design development and regarding the impact of the construction process. In the overall perspective the experiment with the new collaborative design procedures had however worked out satisfactorily. - Something which project managers (and several supplier representatives) explicitly ascribed a very professional and dedicated contribution from the main user representative, a former head of nursing, who had years of experience of working on the interface between users and construction professionals. (See also ‘Facilitation’ below).

\section*{6.6.4. Partners not equal – clear leadership taken}

At several meetings it was obvious that the collaborative process was not an activity executed among equal partners. This observation was supported by the regular conversations with the client’s senior project manager throughout the observation period. The changes in procedures and the use of a new approach were driven by a very engaged trio: the client’s senior project manager, the chief architect and the contractor’s senior project manager. At meetings with suppliers they set the agenda, pushed the process and were in different ways relatively dominant. During the design process there appeared to be a development where suppliers’ representatives gradually became more proactively involved. There was, however, no doubt about the client’s and its nearest partners’ status of being those leading the development and no attempt was made to give an impression that all the involved parties held equal positions. The client and closest partners clearly took leadership in relation to the project, but pushed participants very hard to speak up and make explicit their views, opinions, interests and the potential problems foreseen or expected. Efforts were made to have problems and disagreements worked out to everybody’s satisfaction.

\section*{6.6.5. Facilitation}

In the process of designing collaboratively facilitation was an important issue. The word ‘facilitation’ was not explicitly used but the client’s senior project manager often referred to ‘linguistic action’ principles from a paper by Macomber & Howell (2003), a publication that (in addition to having inspired and influenced the client organisation’s lean initiative) had inspired him personally to invest efforts into making very explicit agreements with the aim of improving mutual understanding in communication among project participants. The principles were explained to participants and the issue of increased communication awareness promoted. During meetings concerned with design and/or target costing it was observed that also the chief architect and the contractor’s project manager acted as facilitators. Facilitator roles often changed several times throughout a meeting dependent on the issues discussed. In general, the trio did not have detailed agreements about who would facilitate and in what way. They expressed that the facilitator role fell naturally on anyone of them dependent on the issue discussed and the development of the debate. Internal coordination was mostly done \textit{ad hoc} by paying attention to what went on.\footnote{Interview with chief architect and project managers of client and main contractor, November 15\textsuperscript{th} 2004. – Observations from the meetings study supported this interpretation.}
The client’s senior project manager found that the chief architect had provided intense facilitation during feasibility studies and in dialogue with users (activities not monitored as part of this case study). He was very satisfied with what he found was a very good and professional approach to communicating with stakeholders, identifying their needs, wishes and expectations, and he was pleased with the architect’s ability to illustrate to the users how the designers were working with the project and from what principles.

Other examples of facilitation could be observed in relation to the ordinary users who were not experienced in participating in construction work planning. One example was observed in a meeting organised for the planning of some work assignments related to the expansion of the neonatal department. Designers and suppliers needed to find a way of doing the work while enabling the personnel to keep the unit fully functioning. A few nurses from the department participated in the meeting where they appeared to experience some difficulty in following the discussions and they gave an impression of being insecure about the situation that they were clearly unaccustomed to. Both the contractor’s project manager and the chief architect were very active in involving the nurses in the discussion. After a while, and detailed work planning was being done and illustrated in drawings, the nurses were able to identify several issues problematic to the execution of their own work. One example was during the detailed planning of work activities that would require a temporary restriction of an access area. This could become an obstacle to efficient transportation of beds and equipment and was thus important to coordinate with the relevant hospital staff. The suppliers involved were actively seeking to understand the work processes of the department and they proposed a number of possible procedures for executing the work. With the explicit interest of the suppliers the nurses gradually became much more actively engaged in discussions and eventually the suppliers and nurses collaboratively identified a procedure that would allow the personnel to keep the unit functioning with an acceptable level of disturbance. In response to a few previous meetings, that had not been successful in terms of obtaining sufficient user feedback, this particular meeting had been approached differently by the contractor and the architect: they had arranged to have the nurses seated in front of the meeting room and they put a lot of effort into graphically illustrating the work processes discussed and into encouraging the nurses to respond. The chief architect and the contractor’s project manager also put effort into avoiding the coded ‘construction language’ and explained the work in terms that made sense to laymen. An interesting observation was that while this seemed efficient in terms of the communication with the nurses, the architect and the contractor misunderstood each other several times during the discussions (e.g. when the contractor’s project manager used the term ‘phases’ to

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173 This project was one of the parallel projects of the expansion of the medical centre. A few meetings of this project were being monitored in addition to the studies of the ARC project. In addition to sharing the same project management, the two projects had in common a significant number of suppliers and supplier representatives that were involved in several of the ongoing projects of the medical centre expansion. Attending some meetings at projects parallel to the ARC proved valuable since issues of several of the projects were (in addition to the official meeting agenda) discussed among project management and suppliers. During discussions references to other projects were commonly made, and during breaks discussions reflected whatever topics meeting participants found to be the most urgent regarding all of the (sub)projects in which they were engaged.

174 Phase scheduling meeting for neonatal dep., December 8th 2004. In addition to client, contractor and architect, a lot of the suppliers participating in this meeting were also suppliers for the ARC. References to the ARC project were often made.
illustrate to the nurses how certain steps of the work would progress his explanations contradicted with the way the term was used on project level and this resulted in some degree of confusion and miscommunication among the construction professionals).

Facilitation appeared to play an important role also in the management of different decision-making processes, which in several respects were political processes between different interest groups. In addition to the construction companies involved the client side was represented through different stakeholders with different, and sometimes divergent, interests. Where the client organisation’s central department for facility planning and development activities (who had a major interest in bringing potential savings back into ‘the central system’) the local affiliate had an obvious interest in having every cent of the approved budget invested in the medical centre. Also different groups of staff had special interests and a large number of issues were more important to some groups than to others. At meetings this resulted in a good deal of negotiation. The question of ‘permanence’ or stability of the decisions made was often brought up by the project managers as well as by other project participants (during meetings, in conversations with the researcher and in the research questionnaire) who commonly expressed some concern or fear that other stakeholders would seek to exploit potential opportunities to force through changes of previous decisions in the pursuit of own interest.

As the project progressed it became increasingly clear that despite recommendations for (or even explicit orders to) bring forward any worries and disagreements, this often did not happen, especially if it was felt that this would contradict the common opinion. The client’s senior project manager found that the collaborative approach was suffering from participants not speaking up - either because they could not shake off habits from ‘the old way of working’, or because they were afraid of being seen as troublemakers or becoming accused of having a negative attitude if taking a dissident standpoint. In an attempt to stimulate better communicating of disagreements the client’s senior project manager was very active in promoting that frankness was a prerequisite for the ‘Target Value Design’ and that this was expected from all participants: “sitting there not saying anything is not acceptable”. He introduced what he referred to as ‘conflict-based dialogue’ where participants were ordered to challenge the design decisions, express concerns and bring up the weaknesses or risks they identified in the project’s development.

6.6.6. Engaged participants

It was observed that generally people participating in the ‘Target Value Design’ process exhibited a high degree of personal engagement in the work. At different occasions (also during informal conversation during breaks in meetings) several participants, independent of one another, brought up the issue that the project was more than just about the construction of a building. The long-term relations between client and suppliers were often referred to as an incentive for participants to engage beyond the extent of a particular job and take part in developing the collaboration itself. The function of the facilities built was also referred to as a factor motivating engagement. After a meeting where work on the neonatal department had to be planned in cooperation with nurses, an engineer from a sub-systems supplier

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175 Conversations with the client’s senior project manager, September and October 2005.
176 See e.g. (Emmitt & Gorse 2003) for a discussion of this method.
mentioned to the researcher that the nurses’ engagement inspired the construction professionals who clearly felt that the nurses discussed, not from a perspective of budget or contingencies, but from the perspective of saving children’s lives.\textsuperscript{177} An example from the ARC was brought up during a process mapping and evaluation exercise (an evaluation carried out after 50% completion of construction documents)\textsuperscript{178} where a supplier representative stated that he found almost all participants to be very engaged in the project. He referred to the information that suppliers had received about the facility’s function as having been the factor that had contributed to changing participants’ perception of the ARC from being “just a construction project” to a focus on its actual life-saving function which depended, among other things, on a competently executed construction project. He referred to an information movie that he and the other participants had seen in the beginning of the project. The movie had been produced on the initiative of staff representatives and showed the daily function of an ARC and the work of the staff. The supplier found that the movie (that pictured a skateboarding child suffering a serious accident and received given life-saving treatment at an ARC) had made a big emotional impression on those who saw it and it had succeeded in illustrating the importance of the project they were going to execute.

A high level of dedication was also observed at a Lean Coordinator’s Meeting, which was a loosely organised forum for the client’s suppliers’ lean coordinators. This group of people regularly spent an evening debating a chosen theme and sharing their views and experiences on issues of developing and implementing lean construction procedures.

The client’s senior project manager and lean coordinator found that the team on the ARC largely consisted of some of the most competent and engaged people in the local construction business. Uncompromised engagement was an absolute demand when working for him, especially on the projects that were explicitly given top priority in the process of developing improved business procedures. As he explained his policy to the researcher: “If you’re not engaged, you’re out!”\textsuperscript{179} There were examples of supplier representatives being removed from the project if the client’s senior project manager found that the person did not commit to some of the basic cooperation principles of the collaborative design process (see below).\textsuperscript{180}

\textbf{6.6.7. Change of participant roles and working processes}

The target value design process represented not only a different way of working but also implied changes to the roles of those involved. Where suppliers were to provide feedback and input, designers were to structure their work in a way that would enable this. Likewise, design work should be structured so that suppliers’ feedback and input could be sufficiently incorporated in the progressing design.

The contractor’s project manager expressed that he had been a little worried about how this would work out in relation to designers who he feared would feel uncomfortable finding ‘their domain’ so intensively challenged. However, experience had proven his worries needless because everything had worked well and designers

\textsuperscript{177} Phase scheduling meeting for neonatal dep., December 8\textsuperscript{th} 2004.
\textsuperscript{178} Process mapping exercise and group interview, October 6\textsuperscript{th} 2005.
\textsuperscript{179} Conversation with the client’s senior project manager, October 6\textsuperscript{th} 2005.
\textsuperscript{180} The precise circumstances were not studied in relation to this case study.
been very positive and obliging; “though at times I really felt we were standing on the
toes of the designers”.\textsuperscript{181}
The client’s senior project manager often emphasised the importance of everybody
“buying in” on the experiment of the target value design procedure, and that he would
not accept participants clinging on to what he called “a narrow definition of their
traditional roles”. By this he meant that no designer should see his/her role as being
concerned only with design and no supplier should consider his/her role as being
limited to a supply job \textit{per se}; design, production planning and cost management was
a responsibility of everybody. An interior designer employed by the architect had
been removed from the project after the client’s senior project manager had publicly
reprimanded him during a meeting where he found that the designer only focussed on
design and refused to consider cost and production perspectives.\textsuperscript{182}

\subsection{6.6.8. Reduced importance of cost data bases}
Participants expressed that, when comparing to previously applied procedures, the
existing cost data bases had been of relatively minor importance when price-
estimation had been done through ‘Target Value Design’. Instead real-time market
prices had been obtained through the design involvement of suppliers.\textsuperscript{183}

\subsection{6.6.9. Set-based design processes}
Few examples of collaboratively coordinated set-based design processes took place
when the project was studied. The by far most important issue dealt with through set-
based processes concerned the design of the water chiller system which will be
illustrated in the following example:

\subsubsection{6.6.9.1. Example: design of water chiller}
In the original schematic design, the new ARC and the expanded emergency
department were to be supplied chilled water from a new 400 tons chiller. This
capacity was equivalent to the existing guidelines for this type of facility.
Early in the design process the suppliers were asked to propose initiatives that could
bring down cost without compromising design intent. The engineers of the main
mechanical supplier, who was also to design the water-supply systems, proposed that
special attention should be directed to the chilling capacity of neighbouring facilities
of the existing medical centre. A brief examination of these led the engineers to
suspect that the existing systems would perhaps possess a capacity sufficiently high to
supply also the new ARC and the expanded emergency department. The engineers
brought this up with the architects, designers and the other suppliers. This was during
winter 2004/2005 when the demand for chilled water was at its lowest and the
hypothesis was thus difficult to test. It was decided to re-structure parts of the design
schedule in order to proceed with a set-based design approach to the chiller system
and intersecting systems. In the following months the designers kept their possibilities
open regarding a design with the 400 tons chiller and an alternative design solution
that relied on supplies through existing systems. The design schedule was re-
structured so that the ‘last responsible moment’ for carrying the final decision would
be after the warmest summer months of 2005 when measurements on the existing
system could tell if capacity was already sufficient. For a small cost the chiller system

\textsuperscript{181} Process mapping exercise and group interview, October 13\textsuperscript{th} 2005.
\textsuperscript{182} Conversation with the client’s senior project manager, October 6\textsuperscript{th} 2005.
\textsuperscript{183} Process mapping exercises and group interview, October 6\textsuperscript{th} and 13\textsuperscript{th} 2005.
suppliers installed measurement devices on the existing systems and flow data from the summer’s peak demand periods proved that the new 400 ton chiller could in fact be removed from the programme. This would bring savings of $1.0 million. The flow measurements on the existing systems did however also prove that the existing chiller systems operated with a vast over-capacity during the low-demand months of the year. This meant that the system was running with unnecessary high operation costs during the coldest months of the year. An analysis indicated that large energy savings could be achieved if the hospital could shut down one larger chiller and instead operate with a smaller 250 tons chiller during low-demand months. Changing the design from the 400 tons chiller to a 250 tons model would save $250,000 in construction costs. Additionally this chiller would bring large energy savings during operations and thus pay itself back over a period of a few years (dependent on the development of energy prices which were at the time increasing significantly). An additional benefit of this choice would be the reduced environmental impact by savings in energy consumption.184

The exercise thus resulted in significant cost savings and enabled designers, client organisation, the local hospital affiliate and user representatives to prioritise design decisions from a value perspective, i.e. opt for the solution that they found would be the most advantageous.

When this conclusion was reached the project economy was still developing according to budget, since designers and suppliers had collaboratively managed to find new solutions within the cost targets whenever early cost estimates had indicated that design developed in directions where established cost targets were likely to be exceeded. Being hesitant to celebrate a success before the final project costs were fully known the design team and steering committee decided to postpone the final decision about adopting the 250 ton chiller solution. Instead a new design schedule was made and the set-based design approach continued in order to keep all possibilities open, until the ‘last responsible moment’. The final decision about whether to save the full $1 million by excluding a new chiller from the program, or alternatively opt for a smaller model, was postponed until a more detailed overview of the total project costs was achieved. After 50% completion of construction documents, when the case study was brought to an end (October 2005), no final decision regarding this matter had been carried.

6.6.10. Collaborative design found time consuming

The process of collaborative designing was very time consuming all through the early design phases. Participation in and preparation for meetings for setting and revising cost target, collaborative design reviews and related activities required a lot of time from designers, suppliers and project management. However, the project managers found that this time had been well spent as every ‘run’ had revealed issues of which they had previously been unaware.185

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184 In construction there are from country to country (and from organisation to organisation) significant differences between prevailing approaches to dealing with environmental issues, conduction of life-cycle analyses etc. In the specific case, environmental aspects of energy consumption was an issue of which designers were aware, but it was not a highly prioritised value and design parameter to the extent often seen at some European projects. (For an example of radically different expectations and demands to environmental aspects of a construction project, see Case II (Chapter 5)).

185 At various project meetings during the winter 2004-2005 this was often stated by the client’s senior project manager.
When evaluating the process after 50% completion of design documents it was the project management’s impression that the time spent ‘up front’ had been saved during later design stages when progress benefited from more thoroughly worked through project material and relatively few design changes. During the evaluation exercises in October 2005 the project managers (client, architect, contractor), the main user representative and participating supplier representatives agreed that much time was still spent discussing and negotiating design solutions during later project stages, but that these discussions had, to a very large extent, concentrated on optimising value-delivery within the possibilities. This was perceived to be very different from “usually spending the time controlling the damage when forced to cut costs”.\textsuperscript{186} One problem mentioned by the architect in the questionnaire survey\textsuperscript{187} was that target costing procedures had ended up requiring more meeting activity than originally anticipated and which had been accounted for in the architect’s contract. Among other themes this issue was openly discussed during breaks in the evaluation exercises. Participants appeared to agree that one learning outcome from the project was the necessity to rethink their own project design cost estimation to reflect the changes in project involvement.

### 6.6.11. Authorities’ approval processes was a bottleneck

Design management processes in relation to OSHPD (the public authority approving the project material) were in many respects very influential regarding the design process. To a large extent design activities had to be organised and scheduled according to the approval process rather than from a perspective of the overall process of designing, building and delivering value. The latitude for organising the design process according to principles of the lean initiative was limited by the constraint of OSHPD, that in many respects were to be considered a member of the supply chain that did not, and could not, actively involve in the value delivery process. In fact OSHPD was limited to either approve or disapprove submitted documents. The approval processes of OSHPD were essentially large ‘batch and queue’ processes into which documents were submitted through a logistical ‘push’ approach. This contradicted the ‘pull’ approach which was a general principle of the lean initiative and it provided a constraint to how far intentions could be applied to the overall project perspective.\textsuperscript{188}

When evaluating the target value design method after 50% completion of construction documents, the project management concluded that the new method would have a positive effect in relation to the OSHPD approval process. This was because the submitted material had been unusually well worked through and contained only few open questions regarding the further process and design development.\textsuperscript{189}

The approval process was a source of much concern and debate throughout the design phases. According to the chief architect, a major design challenge was estimating how some of the building codes would be interpreted during the OSHPD approval process.

\textsuperscript{186} Process mapping exercise and group interview, October 6\textsuperscript{th} 2005.
\textsuperscript{187} A questionnaire (see Chapter 2 and Appendix 3) was in the spring of 2005 distributed to project participants central in the design process, but only seven participants responded. The questionnaires did however contribute with information used for preparing questions for the group interview in October 2005.
\textsuperscript{188} For a discussion on ‘push’ vs. ‘pull’ systems, see Chapter 3.4.2.1 or (Hopp & Spearman 1996).
\textsuperscript{189} Process mapping exercise and group interview, October 6\textsuperscript{th} 2005.
process. This was problematic in several respects. One of the problems was that new design solutions often ended up losing to much less optimal solutions that experience suggested were very likely to be approved by the OSHPD. Such suboptimal choices were often seen as advantageous from the perspective of obtaining a high degree of certainty that the project could progress satisfactorily and not become halted by OSHPD rejection. Participants’ experiences with OSHPD approval processes were often debated in design discussions during different meetings. In this respect it was problematic that approval clarification could not be obtained as part of the target costing process when participants collaboratively developed and verified design solutions. The researcher brought up these observations with the client’s senior project manager (and lean coordinator) who told that the approval procedures were in principle his biggest obstacle for developing and applying project procedures in accordance with the ‘Five Big Ideas’. If the possibility had existed he would gladly compensate OSHPD for involving actively in the projects and provide continuous feedback throughout the design process. Hereby it would be possible to obtain a smoother flow of design work and receive faster feedback on innovative solutions, while avoiding having to submit large batches of work for approval which would extend project durations and imply other unwanted side effects. He emphasised that he would at anytime be ready to cover all the expenses that OSHPD would have from such engagement, and on top of that he would gladly still pay the ordinary OSHPD fee of 1.6% of the construction costs. This, he assured the researcher, would be money well spent and significantly increase the possibilities for achieving savings on the projects and also enhance the value delivery. He was convinced that such procedures would also increase OSHPD’s scope for serving its purpose of protecting the people of California from the building of dangerous or inappropriate facilities. The senior manager believed that active involvement and possibilities of contributing with the authority’s expertise could potentially strengthen the project parameters and enhance innovation.

6.6.12. Controlling risk; a top priority in the supply chain

To participating suppliers the issue of obtaining and keeping control over cost-development was perceived as more important than reaching ‘in-depth cost reduction’. After a successful target costing exercise where architect, contractor, client and subcontractors (in total about 20 participants) had spent half a day identifying cost-saving measures and bringing cost development down by approximately 8% to meet the targets budgeted, the client’s senior project manager asked the participants to declare which success criteria they found should be most important for the further work on the particular project: efficient control of cost development or significant cost reduction? All pointed at control of cost development as the most important. This was in line with the concern about possible cost escalation (with all its consequences of cost-cutting, project changes etc.) that were mentioned in the few questionnaire responses received, and an issue often brought up at meetings where it was often referred to as a major obstacle to optimising planning and performance.

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190 Group interview, November 15th 2004; conversation with the client’s senior project manager, October 13th 2005.
191 If comparing to Krafik’s (1988) original distinction between ‘robust/buffered’ and ‘fragile/lean’ production approaches (see Chap. 3.2.1) these are examples where the project strategy focussed on robustness rather than leanness.
192 Conversation with the client’s senior project manager, October 14th 2005.
6.6.13. Divergent interpretations of project’s development

During meetings it was observed that participants frequently had divergent interpretations of the how the development of the design had progressed. Examples of divergent interpretations could frequently be observed during design discussions which often revealed a missing common understanding regarding what design aspects that at a given time were fixed and which that were still open. It was sometimes hard or impossible for a non-participant observer to say if, what appeared to be a difference in interpretation, actually derived from divergent interests and stakeholders trying to influence the project for their own advantage (e.g. through pushing for a certain solution or regular scope creep). – Discussed below.

During an evaluation exercise after 50% completion of construction documents some key participants were supposed to map the development of the project - which appeared to be surprisingly difficult. Participants exhibited very different recollections and interpretation of what had prompted a certain course of development. This exercise thus lasted considerably longer than first expected and participants agreed to continue the mapping assignment over one or more future meetings. When retrospectively discussing the process the project participants were often surprised how far back decisions could be tracked and identified as deriving from circumstances that not all project participants had been aware of when taking part in the decision making.

The mapping exercise appeared to be more than just an activity of identifying what had hitherto happened. Also here political processes could be observed: there was at least one occasion when participants sought to influence the mapping discussion to reflect their positions in a minor conflict about priorities made. In this specific example the architect explained that six rooms had been cut out of the design in order to make room in the budget for the inclusion of a 250 ton water chiller (discussed above). In the architect’s version she had sacrificed six rooms so that “the engineer could have his chiller”. However the version told by the client’s senior project manager was that the actual reason why the six rooms had been cancelled, was that the architects had developed a proposal above the programme/brief and sketched 46 bedrooms though the programme had specified only 40. This issue was again brought up (by the chief architect) in the continued process mapping meeting where the client’s senior project manager, in response, stated his own different perception of what had happened. The discussion ended here without indication of whether this represented a shared understanding of the process.

After long discussions process maps were gradually developed (under much backtracking and editing) for the schematic design phase (see Figure 6.5) and the design development phase (see Figure 6.6).

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194 Process mapping exercises and group interview, October 6th and 13th 2005.
195 An interesting observation from the mapping exercises (October 6th and 13th 2005) was that it appeared that participants – more than mapping the events and tasks as they had taken place - tried to make sense of and establish a shared understanding of what had actually happened.
196 Process mapping exercise and group interview, October 6th 2005.
197 Conversation with client’s senior project manager, October 6th 2005.
198 Process mapping exercise and group interview, October 13th 2005.
6. Case III: Extension of a medical care centre in California

Figure 6.5: Process map over the schematic design phase of the ARC project.

Figure 6.6: Process map over the design development phase of the ARC project.
6.6.14. Interaction with other projects
In addition to the project managers representing client, architect and contractor, several suppliers were involved in some of the other parallel projects on campus. During meetings references to these projects were often made (e.g. to how a specific solution had been worked out, or certain experiences obtained). At the end of ARC specific meetings, or during breaks, it could be observed that participants often used the possibility to discuss or coordinate issues related to these other projects.
At one occasion the circumstance that projects were undertaken in parallel provided some flexibility that was used by the client to have some assignments moved from one project to another. Hereby it was possible to stay within budget of both projects and to utilise synergies from a supplier’s involvement in both projects.199 From the case study it was not possible to draw conclusions as regarding to whether the continuity between multiple projects had contributed to stimulating team learning for the benefit of efficiency.
The difficult conditions of the construction sites on the campus forced suppliers to enhance communication and coordination about the site logistics, but it was not the impression of the client’s senior project manager that this had contributed to improved communication and cooperation regarding other project issues.

6.7. Summary of findings
The case study highlighted several aspects of lean application to design/construction integration. As for the two other case studies the findings will be further discussed in Chapter 7.
To summarise: the case study illustrates some of the complexity of applying the lean philosophy to the wider project delivery processes. Despite a highly integrated project delivery team and an ambitious and collaborative approach to lean implementation, external factors (such as partial incompatibility with rules regarding procedures for building authority approval) enforced some constraints on the extent to which an integrated lean approach could be taken.
Lean elements and integration indicators from the case will be summarised in Table 6.2:

199 Conversation with client’s senior project manager, October 6th 2005.
<table>
<thead>
<tr>
<th>Lean design/construction element</th>
<th>Present in majority of processes</th>
<th>Present in some aspects</th>
<th>Not present at all</th>
<th>Contradictory</th>
</tr>
</thead>
<tbody>
<tr>
<td>Focus on optimising value for client and users</td>
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<tr>
<td>Value stream mapping</td>
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<td>Value unambiguously interpreted in relation to end customer</td>
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<tr>
<td>Waste reduction focus</td>
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<td>Approach value and waste from a system’s perspective</td>
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<tr>
<td>Perfection aspiration</td>
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<tr>
<td>Systematic experimentation</td>
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<tr>
<td>Strategy for building continuous improvement into the process</td>
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<td>Strategy for making improvements permanent</td>
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<tr>
<td>Strategy for strengthening learning and inter-organisational team learning</td>
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<td>Early supplier involvement in design</td>
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<td>Systematic reduction of variability</td>
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<td>Concurrent design of product and production process</td>
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<td>Production control on the entire design/construction process</td>
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<tr>
<td>Simplify organisation</td>
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<tr>
<td>Effective client involvement in design</td>
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<td>Set-based design process</td>
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<td>Process transparency in design</td>
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<tr>
<td>Process transparency in production</td>
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<tr>
<td>Measures to systematically enhance SC collaboration</td>
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<tr>
<td>‘Pull approach’ to design</td>
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<tr>
<td>‘Pull approach’ to production</td>
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<tr>
<td>Long-lasting supply chain relations</td>
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<td>Cost reduction targets</td>
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<td>Securing of continuous work flow</td>
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<td>Levelling workload</td>
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<tr>
<td>Last Planner System</td>
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</tbody>
</table>
| 5S

200 “5S” expresses five simple and popular principles often applied in lean manufacturing as good shop-floor practice. 5S is short for Sort, Set in order, Shine, Standardise, and Sustain.

Table 6.2: Overview of the case findings in the perspective of widely common elements of lean application.

6.7.1. Integration indicators

As was discussed in Chapter 3, Baiden *et al.* (2006) describe a delivery team in a construction project as ‘fully integrated’ when it satisfies the criteria of Table 6.3.

Bo Jørgensen (2006)
From this understanding of integration it is possible to summarise the case studies as follows:

<table>
<thead>
<tr>
<th>Project indicators of integration:</th>
<th>Present in majority of processes</th>
<th>Present in some aspects</th>
<th>Not present at all</th>
<th>Contradictory</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project delivery team with a single focus and objectives for the project</td>
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<td>Project delivery team operating without boundaries among the various organisation members</td>
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<td>●</td>
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<tr>
<td>Project delivery team working towards mutually beneficial outcomes by ensuring that all the members support each other and achievements are shared throughout the team</td>
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<td>●</td>
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<tr>
<td>Project delivery team able to predict more accurately, time and cost estimates by fully utilising the collective skills and expertise of all parties</td>
<td>●</td>
<td></td>
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<tr>
<td>Project delivery team sharing information freely among its members such that access is not restricted to specific professions and organisational units within the team</td>
<td></td>
<td></td>
<td>●</td>
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<td>Project delivery team with a flexible member composition and therefore able to respond to change over the duration of the project</td>
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<tr>
<td>A co-located project delivery team with a new identity</td>
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<tr>
<td>Project delivery team offering its members equal opportunities to contribute to the delivery process</td>
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<td>●</td>
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<tr>
<td>Project delivery team operating in an atmosphere where relationships are equitable and members are respected</td>
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<td>●</td>
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<tr>
<td>Project delivery team with a “no blame” culture</td>
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<td>●</td>
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</tbody>
</table>

Table 6.3: Overview of the case findings in relation to indicators/factors of integration as identified by Baiden et al. (2006).
Chapter 7

Analysis and discussion
7. Analysis and discussion

This chapter aims to answer the two research questions through discussing the findings from the previous chapters: the review of literature and the findings from the three case studies.

The research started with the aim of identifying processes and/or methods and/or issues critical for integrating construction design and production from a perspective of the lean philosophy (research question 2), which prompted a more fundamental research question: is the lean philosophy appropriate as a means for pursuing design/production integration (research question 1). Dealing with the case studies made it clear that aspects relating to value and value management were central to answering the research questions. This thesis shall not engage in a detailed discussion of value management, but the importance of these themes are highlighted along with other more general management issues. Answering research question 1 primarily draws on the literature review while answering research question 2 draws more strongly on the case studies.

7.1. Research question 1:

Answering the first research question – *is the lean philosophy appropriate as a means for pursuing integration of construction design and production?* – is inevitably linked to the question of how to understand the lean philosophy. Answering that question is however tricky since it must necessarily be a question of understanding the lean philosophy in relation to the construction context (discussed in Chapter 3). Thus the two questions are interrelated.

The lean philosophy’s application to construction was first discussed by Koskela in 1992 and explored further by him in 2000. Koskela found the absence of a general philosophy of production to be a missing link for properly understanding the field of ‘producing’, and concluded that such theory must encompass three views of production: production as a transformation process; production as a process of flows; and production as a value generating process. Important findings of Koskela were that the transformation view was the by far most investigated and best understood, while the issues of flow and, especially, value generation were yet to be thoroughly investigated. Koskela concluded that it, in principle, is possible to formulate a general theory that will also be valid for construction. His arguments shall not be repeated here, but it is important to notice that he did not formulate this general production theory that he has continuously been pursuing in his research. Koskela’s work is on a very high level of abstraction and it recognises that practical application of the general theory pursued must necessarily reflect the context addressed (in this case that of construction).

Another aspect is that while the lean philosophy has been discussed in numerous works, its definition remains vague beyond the main characteristics of systematically eliminating waste and improving value generation over a system’s perspective (Chapter 3). For this thesis an important implication is that the lean approach essentially advocates integrated approaches to designing and making. Early publications of Ohno (1988), Shingo (1988; 1989) and Womack, Jones & Roos

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201 For a recent publication on this theme, see (Koskela & Kagioglou 2005).
(1990), that were instrumental in shaping the discourse of lean debate, diffusion and application, emphasised the importance of adopting an integrated approach to design and production. In this understanding products were to be designed to maximise end customer value while enabling delivery through an efficient production process generating only minimum waste, i.e. resources consumed without adding value to the end customer.\textsuperscript{202}

This directly pinpoints a problem associated with adopting the lean philosophy for construction since one of the philosophy’s main pillars, end customer value, that has hitherto received only marginally attention in lean construction debate, displays many intangible characteristics in construction. As will be shown in the following, two obvious, and very problematic, questions are:

\begin{itemize}
\item[a)] Who is the end customer in construction?; and
\item[b)] Is it at all possible to define end customer value and, if so, how can this be done?
\end{itemize}

Providing a satisfactory answer to these two questions undoubtedly requires a doctoral research project of its own, which is outside the scope of this thesis. However, on the basis of the discussion of ‘lean’ and lean construction (see Chapter 3) and the three case studies (Chapters 4-6) it is possible to explore these important questions in a little more detail (discussed below).

As will follow from the discussion of (customer) value, it is necessary to further consider how to understand and assess ‘waste’ from a lean perspective. Before concluding on the appropriateness of the lean philosophy as a means for pursuing design/construction integration it must also be clarified at which organisational levels the integration theme is addressed. Finally empirical findings will be discussed before conclusions are drawn.

\subsection*{7.1.1. Who is the end customer in (lean) construction?}

The lean philosophy advocates ‘end customer value’ as the benchmark for all efforts to address waste and to determine what can be considered value generating/adding, and conversely what cannot. Perhaps the most specific definition is (as discussed in Chapter 3) proposed by Womack & Jones (1996; 2003):

\begin{quote}
“The critical starting point for lean thinking is value. Value can only be defined by the ultimate customer. And it’s only meaningful when expressed in terms of a specific product (a good or a service, and often both at once) which meets the customer’s needs at a specific price at a specific time.”\textsuperscript{203} (p. 16)
\end{quote}

\textsuperscript{202} For a discussion of different kinds of waste, see (Ohno 1988) (discussed in Chapter 3). Within the debate on lean construction Koskela has discussed the interpretation of these wastes and proposed the existence of an 8\textsuperscript{th} waste related to improvisation in order to ‘make do’ (2004b).

\textsuperscript{203} While many publications refer to (end) customer value, very few specify how this is to be understood. This explicit formulation is however very precise, and it is proposed in one of the very most influential publications regarding the lean philosophy and its application to different industries, including construction. Therefore this definition will be adopted as a starting point for the further discussion undertaken in this chapter. - For its interpretation an important question is how to understand ‘price’. To be meaningful for further discussion ‘price’ must obviously be understood as representing not just the price itself but the total costs that the customer will need to bear for the value delivery.
While certain circumstances may make this approach to customer value identification applicable to car manufacturing in Japan (and a number of other industries throughout the world), it is in principle as well as in practice highly intangible in relation to construction.

As has been described by other authors (e.g. Womack et al. 1990; Katayama & Bennett 1996; Boyer & Freyssenet 2001; 2002) the Japanese car industry has always been very dependent on the domestic market, which has remained its main customer base despite the heavy expansion on exports markets where transplants now produce for the big markets in North America and Europe. On the domestic market Japanese car producers have benefited from strict government regulation that in fact protects domestic producers from competition by foreign manufacturers. Government regulation and rigid rules for safety inspection also encourages strongly the replacement of cars after about four years of service, typically for replacement with brand-new vehicles (Womack et al. 1990; Katayama & Bennett 1996). With a limited market for used cars (and with rather low resale prices), producers hence manufacture with reference for one single owner – presumed to be the end customer - who in most cases can also be expected to be identical with the user. Additionally the product developer and manufacturer benefit from knowing the time frame for which the individual vehicle is to serve its end customer. If assuming that value devaluation is constant over the years where a car is in service, the end customer value can be graphically illustrated as in Figure 7.1.

![Figure 7.1: Principle illustration of the development of customer value for a car in Japan. If applying a common accounting technique, writing down the value can be done linearly. – Comparison to a real example about a car driven in the UK (see the next figure) suggests that within this timeframe a linear devaluation is a good approximation for describing the transience of the market value – what the customer is willing to pay for a specific car at a specific time.](image)

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204 Data from the International Motor Vehicle Program suggests that only a third of the used cars are sold for further use in Japan. One third is scrapped because costs of repair are too high for being economically feasible, and another third is exported to markets in South East Asia (Womack et al. 1990, p. 185).
194  Bo Jørgensen (2006)

Figure 7.2: Example of the development in market value for a car in the UK. In this case an Austin Countryman Estate Car. - From (Thompson 1979).

Figure 7.3: Typical long-term development of market value for a building. Opposite to the market value of a new car, the building/land most commonly increases its market value. – To users and several other stakeholders the value is delivered over a long time-span.

In construction the situation is radically different in several respects, of which most are inevitably linked to two of the most distinctive characters of built artefacts: long durability and geographically immobility. As the value of land increases, so does the value of the entire facility (land and building).

While there are examples of buildings serving only a few years, the vast majority end up serving for many years, usually generations, and it is not unusual for buildings or civil constructions to be in use for centuries. Some of the principal differences in characteristics between Japanese car manufacturing and Western construction are illustrated in Table 7.1.

205 This relatively old example has been chosen partly because it dates back to the period where the lean approach was developed in Japanese car manufacturing.
Table 7.1: Some important differences in product characteristics when comparing the two different industries: Japanese motor car manufacturing and Western construction.

A most obvious problem of transferring the lean philosophy from car manufacturing to construction is that of identifying the end customer (or, in some publications: the ultimate customer) for whom to deliver value. Most buildings are meant to last for a
considerable period of time, and even buildings intended and designed for only a few years in use often end up serving for generations and multiple purposes. Contrary to most other goods, a large proportion of the buildings increase their market value over time. Buildings, large buildings in particular, are typically meant to – or end up to - serve practical purposes as well as constituting a mid- or long-term financial investment. If following slavishly (as advocated by Womack & Jones) the lean philosophy with its insistence on end customer value, the client should thus not simply be regarded as the ultimate end customer but rather be considered a middleman; one link among several in the supply and value chain. As such the typical construction client carries elements of an end customer while also being an internal customer and supplier of the entire supply chain. The difficulties of identifying the construction end customer only become increasingly complex when adding the elements of multiple users that are not only different from the owner but also represent different needs and interests etc.

Facing the same difficulties of identifying the construction (end) customer, Koskela (2000) found that customers were likely to be plural, and concluded that “by definition, wider society should be included as one customer.” (p. 78).

Smith (1999) emphasised: “the real value of a facility lies in its ability to enhance the satisfaction and performance of the users, and where applicable, financial returns. (...) After all a building costs money but only its function delivers value.” (p. 167). A consequence hereof must be that value and waste related to delivery of buildings cannot be meaningfully understood without considering a whole-life perspective of the facility.

It follows that in reality the (construction) end customer cannot be unambiguously identified as demanded under the lean perception argued by e.g. Womack & Jones (1996; 2003).

7.1.2. Is it possible to define end customer value?

Logically, if the construction end customer cannot be identified, the end customer value cannot be identified either. If leaving aside the question of identifying the end customer, one can adopt the hypothetical assumption that an ultimate end customer does exist and can be identified. The problem now becomes that of identifying value. At least in principle, this would be possible within a timeframe of need predictability. Other problems do, however, remain:

Womack & Jones (1996; 2003) advocate the application of a value perspective limited to only one particular point in time. The problem is that value and values are known to display a not insignificant degree of dynamic behaviour (discussed below) and that the considerable investment typically needed to realise a construction project, suggests that this cannot be neglected when defining customer value, not even on the short term. Practical issues of defining and managing customer value in construction have been discussed by a comprehensive body of literature, and shall not become a subject of further examination here. However, an important observation is that acceptance of a very short timeframe for defining customer value appears to imply a simultaneous acceptance of possible long-term waste generation or value loss

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206 Suppose, for the sake of argument, that the value for a specific construction project is assessed with regard to only one particular point in time. How can risks then be estimated and managed? How can the client’s return on investment be assessed? Who would finance a project on this basis and what terms and conditions would be demanded for financing projects under such circumstances?

207 A discussion of value management issues in relation to building projects is provided by Green (1994).
disproportional to the possible benefits of this procedure. This would thus be highly contradictory to the lean philosophy’s emphasis on waste elimination.

In relation to lean construction and lean design, issues of customer and stakeholder value have been discussed in a number of publications including (Koskela 2000), (Emmitt et al. 2004; 2005), and (Pennanen et al. 2004). Perspectives of applying procedures of ‘design to target cost’ as part of a lean construction framework for optimising customer and user value with respect to cost have been discussed by Ballard & Reiser (2004), Jørgensen (2005) and Granja et al. (2005). Individual lean construction publications appear to perceive customer value in different ways, e.g. emphasise differently the weighting of interests of the (formal) client vs. those of other stakeholders. Given that construction projects and the contexts in which they are individually embedded (including the nature of customer/user characteristics and the internal relationships between stakeholders) - are extremely diverse, it follows that customer(s) and values must be identified for each project. It does, however, also imply that value identified/specified can reflect only the circumstances that are present, foreseeable or anticipated at the time of the value definition process. Thus these may not necessarily reflect the needs or preferences of the ultimate (end) customers (whoever these may eventually be).

Promoters of the lean production philosophy’s focus on end customer value often (as Womack & Jones) define ‘value’ as ‘the need fulfilment that the client is willing to pay for’. The problem in this approach is that it implicitly presumes that a good is delivered to one specific end customer who immediately consumes it (and perhaps requests a new). Essentially this is a ‘use-and-throw-away’ approach that does not seem fit for application to the production of goods with a very long lifetime and market value and user value that do not naturally devaluate rapidly within a short to medium timeframe.

An elaborate discussion of the consequences of adopting this approach as a basis for value definition under (lean) construction is beyond this thesis. For illustrating the complexity of this, three examples of wicked problems common for construction projects will be briefly introduced and discussed in relation to the lean philosophy:

- **Difficult or impossible to identify future needs and demands:** This problem is well known to construction research and practice, and for this reason facilities management, adaptability and maintenance issues etc. have become established design parameters, as have user requirements. However,

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208 Adoption of target pricing and target costing principles (with the aim of supporting supply chain integration) to construction has previously been discussed by Lædre & Haugen (2002), and by Nicolini et al. (2000). Where the approach studied by Lædre & Haugen focused on partnering contracts and target pricing (which is after all different from the actual costs), Nicolini et al. offer a more detailed study into target costing approaches as they were developed in Japanese consumer good manufacturing. From two case studies Nicolini et al. found that a number of contextual factors impede successful application. The case studies illustrated how construction professionals in fact continued to operate according to the previous practices and how the target costing principles adopted had been only partially absorbed by the participants. At these two case projects the target costing theme was, however, first approached without adaptation of the existing organisational and contractual framework, and (it appears) without sufficient continuous support by strong leadership. Aspects which literature on target costing for manufacturing industries (Cooper & Slagmulder 1997; 1999) have argued to be of crucial importance, and that were addressed in the more promising attempt of adoption of target costing principles that was studied in Case III (see Chapter 6).
adaptability rarely goes much beyond providing flexibility regarding interior walls, possibilities for future extensions and the like. From a lean perspective this often implies considerable waste in the shape of possibilities that may not be made full use of, failure to meet the exact future needs, unnecessary high costs of demolition and disposal etc. As buildings have fixed locations and cannot be conveniently stored aside, efficient system-wide waste reduction and the pursuing of perfection - a key element in the lean philosophy - requires a whole-life-approach addressing not just design, construction, maintenance and adaptation. Also disassembly, material disposal and recycling strategies need to be addressed during design and specification if effective waste reduction is to be obtained.

- **Diverging interests leading to sub-optimisation:** Construction operates under the condition that value specification is principally executed on terms of the client or the client’s representatives, while being more or less influenced by interests of the main project participants (e.g. contractors, architects, users and consultants) and external stakeholders holding various degrees of power. With a building that is likely to be serving most of its lifetime under future users and possibly other owners (and with a client which, as argued above, thus represent a middleman rather than an end customer), it can be argued that the issue of sub-optimisation of client (client representative) decisions in the ‘extended’ construction supply chain (encompassing also in-use phases) must be addressed before construction can become ‘lean’ as according to the production philosophy (that prescribes non-tolerance to sub-optimisation at all stages throughout the supply and value delivery chain). In this respect a particular challenge is the short-term personal interests of decision makers. Issues of corporate managers’ interest in short-termed sub-optimisation vs. other stake- and shareholders’ interests on the long-term development have been a topic of much attention in economics studies, management research, and in law and regulation. Establishing means for enhancing transparency of management action and its wider consequences is a core principle of techniques applied to address managerial opportunism, buyer/supplier sub-optimisation etc. Transparency is also an important element in establishing inter-organisational conditions for applying lean approaches to a large variety of business processes (Ohno 1988; Womack et al. 1990; Braczyk 1996; Karlsson & Åhlström 1996a; Cooper & Slagmulder 1999; Hines et al. 2004). Various decisions related to the investment in built assets often bear considerable economic implications on terms longer than decision-making managers’ reward cycles. But these cannot be effectively assessed or controlled from ordinary budgets and books of the construction project, and neither from those of the client organisation itself. Aspects of sub-optimisation are very difficult to address in any industry and problems of point optimisations still exist among lean producers in the car industry, especially among organisations that have missed to address the strategic aspects of ‘lean’ (Hines et al. 2004). It will hence be reasonable to expect that a considerable potential for waste elimination can be found and addressed through establishment of increased transparency of the implications of various decisions made by e.g. the corporate client (representative). This issue is yet to be investigated in relation to lean construction.
• **Interests of external stakeholders:** Various built artefacts have considerable impact on the surrounding society. Just the single aspect of their long-standing immobility makes them objects of importance and constraints to the neighbouring environment. It can be argued that construction includes elements of extensive societal responsibility, different from that of manufacturing more temporary (and mobile) artefacts. Though important for identifying value in a wider contextual perspective these aspects are usually not addressed in literature that promotes lean application or discusses the underlying philosophy. Koskela (2000) draws attention to this aspect and suggests the adoption of a ‘value loss’ parameter. Despite the need to manage the processes and the impact of diverse stakeholder interests via specifying value parameters, this aspect is yet to be thoroughly discussed in relation to its implication to the philosophy of minimising waste. It is necessary to further examine the scope for managing the impact of stakeholder composition and interest on basic value delivery processes and mechanisms when applying a lean perspective.

In ‘lean’ terms, considerable amounts of what e.g. Ohno (1988) referred to as ‘type II muda’ (waste that it is not technically impossible to eliminate) can be ascribed these late stages of the whole-life supply chain. Dominant titles on the lean philosophy prescribe that such waste must be eliminated (Ohno 1988; Shingo 1988; Womack et al. 1990; Womack & Jones 1996; 2003).

In terms of practical application of the lean philosophy to construction, one of the most holistically scoped lean construction procedures that have been proposed and commonly cited is the Lean Project Delivery System (Ballard 2000b). Originally its focus did not expand beyond testing and turnover, however the system has continually been under development and later publications have suggested the incorporation of learning loops from post-delivery use phases into the definition phases of subsequent projects (Koskela et al. 2002; Ballard & Howell 2003a). But yet all lean construction procedures (like any construction management approach known to the author) suffer from the lack of efficient means to optimise the project delivery with respect to the long term perspective beyond the horizon of predictable conditions. Few lean construction concepts address project delivery beyond handover. If adopting a critical perspective, this limitation can be viewed as principally representing a shortcut for avoiding the need to address the somewhat wicked and intangible problems deriving from the client not automatically constituting the final end customer. The easiest way of getting around this tricky problem is to adopt the assumption that construction serves one customer only, and hence define the client as the end customer. Most commonly the life-cycle of the building, after it has been delivered, appears to be widely ignored. While (implicitly) this approach is very common in publications on lean construction, it does in fact compromise not only the end customer focus promoted by the lean philosophy, but it also violates what appears to be one of the

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209 Koskela cites Taguchi (1993) for proposing that this loss can be expressed by a quadratic function of the deviation from target value to user and wider society. (p. 78)

210 Many publications on lean make – often to a considerable extent – use of Japanese terms. ‘Muda’ refers to waste and is commonly used for every resource spent that does not directly add value as it is perceived by the end customer. (See Chapter 3 for an introduction to ‘type I muda/waste’ and ‘type II muda/waste’).

211 See Chapter 3 for an introduction to The Lean Project Delivery System.
main lean principles by accepting principally removable waste at the expense of
pursuing perfection. The lean philosophy (as according to e.g. Ohno 1988; Shingo
1988; Womack et al. 1990; Womack & Jones 1996; 2003) does not approve of
accepting problems of organisational character as an excuse for omitting to address
waste.

7.1.2.1. Dynamic properties of value:
In addition to the principally practical or technical problems of determining
stakeholder value, efficiently manage decision processes and foresee the development
of long-term needs and interests etc., there is a problem of more philosophical
character connected to determining value of built artefacts under the application of a
lean approach that adopts a holistic perspective on value enhancement and waste
reduction/elimination:
Value parameters - and the perception of value - are dynamic over time and it is
possible that artefacts (or features of artefacts) that are at some point perceived as
waste or as valueless, over time start to represent a significant degree of value.

In building and construction this is not just a philosophical issue, but in fact also a
very practical one. This theme has been elaborately discussed by Thompson in his
doctoral thesis and subsequently in (Thompson 1979) where he argued that if artefacts
such as buildings become old enough, they will at some point become of durable and
commonly priceless value. The examples discussed by Thompson can be considered
as ‘critical cases’ regarding the question of whether it is in fact possible to determine
the ‘end customer value’ in construction.
From a standpoint in his academic discipline, philosophy, Thompson offers an
elaborate discussion on what can be understood by value and how it differs from what
does not represent value (which he refers to as ‘rubbish’). Thompson argues that
principally two kinds of value exist - transient value and durable value - and that it is
only possible to produce physical artefacts that are of either transient or of no value,
while as good as nothing (with few exceptions that cannot be predicted in advance)
can be produced to represent durable value from the very beginning. Artefacts of
transient value will by time devaluate and/or fall into decay and become
valueless/rubbish. Nevertheless, in most cases such ‘rubbish’ will at some point regain
transient value or suddenly become of durable value. But, Thompson argues, it is not
possible to forecast when this happens. It may happen tomorrow but it may well take
centuries.212 This represents several practical problems when assessing the value of
buildings that are artefacts of very long durability and of multiple stakeholders.
Thompson provides specific case examples from the UK where old houses and
dilapidated quarters of ‘rat-infested slum’ when on the verge of being demolished
suddenly gain status of ‘glorious heritage’ in the minds of influential groups of the
public. In these examples this development results in far-reaching consequences such
as public demand for preservation listing and consequential need for rethinking the
entire district development plan. One of Thompson’s conclusions is that if allowed to

212 An important aspect of Thompson’s theory is, however, that transient value does not transfer
directly into durable value but only into rubbish. Only under certain conditions can the transfer from
‘rubbish’ into durable value take place. This is determined by, among several factors, cultural and
social factors that are the missing elements in the model and this prevents prediction of whether durable
value will in fact come into existence. Economical theory address only transient value and the valueless
and thus it often falls short of forecasting the development in perceived value of e.g. certain built
artefacts (Thompson 1979 Chapter 3).
stand for long enough buildings will at some point inevitably become of durable value and, when old enough, cultural heritage and priceless.

Value aspects of construction has been discussed in numerous titles but one argument bringing in Thompson’s work in the present discussion is that he discusses value from a perspective that has many features in common with that of the lean philosophy. Value is discussed from the perspective of the customer and held against what is of no value to him/her (in lean terms ‘waste’ and in Thompson’s ‘rubbish’). By incorporating the essential parameter, time, in the considerations Thompson illustrates that value does in fact exhibit highly dynamic properties and that this has far-reaching implications for assessing value of durable goods. - Not least in the case of buildings that are special in the sense that they easily end up having very long life times, they are investment intensive, location-fixed and they typically possess multiple stakeholder properties.

Publications on the lean philosophy rarely mention time aspects of value delivery others but those directly connected to response and cycle time (e.g. time from order to delivery). While a few publications on lean construction recognise that value and values change over time the long-term value perspectives remains an issue to be investigated considerably further before waste elimination/reduction can be effectively addressed over the whole-life perspective.

7.1.2.2. Conclusion
For the discussion on lean construction it follows that operating from a perception of customer value that is determined with reference to only one definite moment in time (as proposed by Womack & Jones) is inappropriate for general application to the built environment.

Perfect identification of all long-term customer and user value is principally not possible which thus limits the degree to which the lean approach is practically applicable to construction. Systematic enhancement of customer/user value and elimination/reduction of what does not add value (waste) cannot be applied beyond the extent that the value aspects are understood. That such limitations exist does however not imply that the lean philosophy cannot be useful to practical efforts of improving value and waste performance of construction or as a means for construction design/production integration, dependent on what subsystems that are addressed (discussed below).

7.1.3. Is it possible to identify waste?
The lean philosophy defines waste as what does not add value to the end customer. For the philosophy’s application to construction it implicitly follows that if it is not
possible to identify fully what does in fact represent end customer value, waste cannot be thoroughly identified and addressed either.

In practice, however, a not insignificant range of waste and wasteful activities can still be identified. Activities such as e.g. corrections and rework etc. are obviously connected to consumption of resources that do not generate value for the client or any future users regardless of how a facility does or does not represent value to them (see footnote 222). The seven types of wastes identified by Ohno (overproduction, correction, material movement, processing, inventory, waiting, and motion)\textsuperscript{216} can be addressed during design and assembly in the pursuit of a resource efficient project delivery process, but in the larger end customer perspective this does not necessarily imply that the delivery process is waste efficient. Taken to the extreme, constructing a building, or another facility, that eventually proves to be of no value and should never have been built in the first place, is nothing but waste, regardless of how resource-efficient the delivery process has been.\textsuperscript{217}

To conclude, waste can only be effectively identified and addressed to the degree to which end customer value is known and understood. This principally marks an upper limit to which the lean philosophy is useful as a means for addressing waste in construction.

**7.1.3.1. Waste and costs not affecting the (end) customers or the supply chain**

From literature on ‘lean’ there is little clarification regarding how the theme of waste and costs not affecting the supply chain or (end) customer(s) is to be dealt with in accordance with the ‘lean’ philosophy. Principally, it appears, the lean philosophy is concerned only with waste and costs as perceived by the supply chain and (end) customers. The lean philosophy focuses on customer value and of minimising resources consumed without contributing to end customer value. It can – dependent on the interpretation of the philosophy - be argued that the lean philosophy implies a self-contradiction in this respect if the solution most waste-/value-efficient in relation to the client and/or supply chain is not the most waste-efficient from an overall perspective when taking into account the effects on other stakeholders.

The lean philosophy promotes unambiguous orientation towards end customer responsiveness and at the same time ‘zero tolerance’ to waste that it is possible to eliminate, but these two focus areas may not always be compatible. The problem is that the lean philosophy does not take into account that other stakeholders but end customer and supply chain are affected by the value delivery process. This is of significant practical importance which can easily be illustrated through practical examples related to environmental impact of a built facility and/or of the construction delivery process. To illustrate with an example: Client, users and the entire supply chain may be completely indifferent in regard to the environmental impact that the production of a chosen material – which may represent high client

\textsuperscript{216} See Chapter 3.

\textsuperscript{217} While this example is extreme, it is in no way hypothetical. While rare there are however numerous examples of facilities that have been built without ever being taken into use. In some examples buildings have been demolished even before their completion. – Such examples also illustrate how the dynamic properties of the value of built artefacts provide a bad match with pursuing customer value defined only with reference to a single point in time. An approach promoted by (Womack & Jones 1996; 2003).
value – has on the surrounding environment where it is produced. What may be a waste-efficient value delivery process when seen from the perspective of the client, users and the supply chain, may in fact come with a disproportional cost to other stakeholders not considered part of the delivery system. An issue not addressed by the lean philosophy. If following slavishly the principles promoted by e.g. Ohno (1988), Shingo (1988) and Womack et al. (1990), end customer value, needs of internal customers within the supply chain, and minimum needs for efficient production should be the only references for all production dispositions. It implicitly follows that under compliance with the lean philosophy, as it is promoted by these authors, negative consequences to other parties are of no interest per se.

However, if adopting the suggestion by Koskela (2000), that wider society should be considered a customer of construction (which was further discussed and argued above), all such negative impacts and deviations from optimal value should be considered as waste and thus be addressed under a lean approach.

7.1.4. Purpose of design/construction integration

A precondition for judging an approach’s appropriateness or suitability in relation to design/construction integration is knowledge about the purpose of such integration. However, since the lean philosophy applies a holistic perspective which in principle involves all organisational levels of a supply chain, it must first be clarified on what organisational level(s) the theme of integration is discussed.

7.1.4.1. Organisational level of design/construction integration

The features that Baiden et al. (2006) found to characterise a fully integrated construction project delivery team all link back to integrative processes which can be seen as connected to different organisational levels (see Chapter 3). For the further discussion in this thesis it is necessary to specify more precisely the organisational focus adopted.

Simplified, the theme of design/construction integration can be approached at one or more of three different, but interdependent and interconnected, organisational levels (discussed by Jørgensen et al. 2004a):

1. A level of basic issues of organisation, coordination and collaboration;
2. A level of business/market structures and regulation, and;
3. A level of political processes reflecting different interests and the power/influence of major construction sector stakeholders.

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218 Any production philosophy or approach can be applied in cynical disregard of ethical issues. The purpose behind bringing forward this example is not to discuss the ethics theme but to illustrate how context adds considerable complexity to practical questions of determining what in a given situation should be considered waste (and if such waste is of ‘type I’ or ‘type II’) under the application of the lean philosophy.

219 Publications discussing critically working conditions and environmental impact etc. under the Toyota Production System (see Chapter 3) seem to suggest that this might be the actual interpretation (at least partly) followed by ‘lean’ role models. However, as was also discussed in Chapter 3, the way issues of construction health/safety problems are part of the lean construction debate shows the co-existence of a much more pragmatic (and sympathetic) interpretation of the lean philosophy.
The lean philosophy (and publications on its application to construction) addresses primarily the level of organisation, coordination, cooperation and production, or in other words: the level of supply chain processes (level 1, see Figure 7.4). However, as was discussed in Chapter 3, ideas and common practices have developed in context and reflect business/market structures as well as more fundamental patterns of interests and power under which the automobile industry operated during Japan’s industrial expansion in the second half of the 20th century. Since the lean philosophy principally applies a system’s perspective throughout the supply chain it is in practice impossible to avoid especially the level of business/market structures and regulation (level 2) when implementing lean initiatives that affect procedures beyond the limits of the individual organisation. After all, such initiatives are to function in the context of a supply chain in which cooperation and business processes are to a significant degree subordinate to business structures, rules and regulation, and will be heavily influenced by institutionalised practices of the sector and the markets on which it operates (discussed below).

Research by Thomassen (2004) illustrated that while inter-firm organisation and structures of collaboration may be irrational in terms of productivity and customer value delivery, as well as from a wider macroeconomic perspective, they do in fact often represent rational behaviour for the individual construction company seeking to optimise profit performance and protect itself from consequences of uncertainty and demand variability. Thomassen’s findings support strongly the argument that technical advantages of e.g. integrated design/construction procedures are difficult for the construction industry to adopt if inconsistent with existing organisational patterns that have developed in response to structural factors. It follows that evaluating profitability and overall benefit aspects related to adoption of the lean philosophy is a very complicated task, and that the issue of profitability cannot be studied in complete separation from the structural context in which implementation takes place.

The second level (business/market structures and regulation) is to some extent touched upon by the lean approach of structuring the entire supply chain all from the

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220 This was also illustrated by the empirical findings from the case studies (see chapters 4-6) which will be discussed later in this chapter.
perspective of delivering value to the end customer in the way that over the system’s perspective generates the less waste. The micro level of the (technical) production system is, however, the primary focus of the lean framework, and was also the centre of the lean initiatives represented by the three case studies of this research (chapters 4-6).

The third level (political processes and underlying stakeholder interests and power) is not addressed by the lean philosophy, which is therefore not suitable as a means for pursuing integration issues on this level.

Considering the primary organisational focus of the lean philosophy and prevailing methods for its application, this thesis will adopt the micro level (the level of supply chain processes) of basic issues of organisation, coordination and collaboration as the focal point for discussing the lean philosophy in relation to the theme of design/construction integration.

7.1.4.2. Primary purpose of applying a lean approach to design/construction integration

Essentially the lean philosophy addresses productivity and production organisation, and in most publications questions of value are primarily approached from the perspective of productivity (see Chapter 3). In practice the main objective for design/production integration is, however, unlikely to be improvements in productivity (nor waste elimination/reduction) first and foremost. Nevertheless, profitability - which depends on a number of factors of which productivity is but one - is not directly addressed by the lean philosophy. While profitability aspects would definitely be a very relevant theme for thorough investigation, it can be argued that a more fundamental issue to investigate in relation to integrating design/construction from a lean perspective are aspects of waste and value performance since this is what the lean philosophy itself is first and foremost concerned with.

As discussed above, profitability issues cannot be studied in separation from the structural context in which the individual construction organisation and project is embedded, and examination of the issue would require more data than was available from the case studies of this research.

Design/construction integration from the perspective of the factors central to the lean philosophy: value enhancement and reduction of total resource consumption affiliated with delivering (customer) value, are addressed later in this chapter.

7.1.5. Empirical findings

The two questions of identifying the construction end customer and of defining end customer value are far from only theoretical. All three case studies illustrated that also in practice these questions provided difficulties and sometimes real problems to both the clients and in particular to the design teams. Though the term ‘value’ was not always explicitly mentioned by designers and other project participants it was clear that they were in general concerned with questions about client and user value.

Something which provided important reference points in arguments behind design

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Bo Jørgensen (2006) 205

221 Productivity will commonly be of high importance to profitability but linear correlation between productivity and profitability does not necessarily exist.
decisions and for discussions among participants. When sufficient clarity regarding client and user value was missing this was reflected in discussions regarding a large number of design and production decisions where uncertainty on value matters had an impeding effect on possibilities for applying an integrated approach to design and construction processes and for pursuing leanness through minimising value and maximising waste.

In the case studies especially two issues stood out as having impacted processes of integrative design and production preparation: stakeholder influence and authority approval processes.

7.1.5.1. Stakeholder influence: direct and indirect influence on project delivery processes

Stakeholder influence on project development and design was found to be significant. From a perspective of design/construction integration, important observations were that not only design phases were affected. In all three case projects the scope for preparing a ‘lean’ production phase was (to different extents) reduced due to difficulties and uncertainty deriving from intangibility of customer and stakeholder values, interests and positions. Difficulties of forecasting what positions individual stakeholders (individual, groups or organisations) would adopt and of estimating their relative influence on project processes appeared to be key factors that caused different degrees of uncertainty regarding client decisions and their stability. Changes to previous client decisions may be carried at stages where some parameters have become fixed why certain changes will inevitably result in suboptimal designs where better solutions could have been reached provided that the final client decisions had been known (or the change anticipated) at an earlier stage.\(^{222}\)

To different, but significant extents, this affected the case projects’ design teams’ latitude for optimising the design with respect to value delivery, while also decreasing the scope for concurrently design, plan and prepare for a resource efficient production process. In the three case projects such challenges were handled very differently, reflecting very diverse project circumstances.

7.1.5.2. Authority approval processes

An issue that has hitherto been largely overlooked in lean design/construction debate are the mechanisms of public authority approval processes and their influence on the design, planning and production preparation processes. The two case projects that

\(^{222}\) Principally the issue discussed is not just if the client changes a previous decision or not, but if the client changes opinion in regard to what is wanted or needed from the project in order for it to provide the value required. With a change of mind follows a relative reduction in client value delivery unless action is taken by the project team to alter the project to reflect the client’s new preferences. Such changes will however generate waste (e.g. through rework). Such waste may be necessary for the right/better solutions to be generated through learning and iteration, but it is of course problematic if such iteration does not take the design forward (in relation to value delivery and detail) because the design iteration process builds on false assumptions regarding client and stakeholder value. It follows that ‘leaness’ with respect to the client is dependent on, among others, two parameters: 1) the degree of conformance between client decision and what does in fact represent client value, and 2) the waste consequences of changing a previous decision in order to enhance this conformance. Thus a fully ‘lean’ delivery process cannot be pursued through efficient production processes alone unless perfect concordance between design and client value can be presumed, which is however hypothetical. In addition to calling for a meticulously conducted briefing process this also prompts a design and production planning process with some degree of flexibility for changes reflecting the uncertainty regarding the design’s concordance with optimal value delivery over time.
were studied during phases of detailed design (case II & Case III) both illustrated that the interaction between project organisation and building authorities in a number of respects are decisive to the possibilities for organising and executing projects in accordance with the lean philosophy, ideas and tools applied.

Building authorities are generally considered as a stakeholder in construction. If adopting the view of Koskela (2000), that wider society should be considered a customer in construction (discussed above), it can be argued that building authorities represent one among several customer representatives. This customer’s function is to protect society from undesirable consequences of bad construction. Under this perception construction design have three objectives in relation to the building authorities:

1) To deliver design solutions in accordance with rules and codes;
2) To obtain approvals; and
3) To enhance delivery ‘building authority value’.

While 1) and 2) are obvious, the third point may require a little more explanation. The basic function of building authorities is to protect society from consequences of bad/wrong construction, or in other words: to provide the individual citizen a guarantee that all buildings fulfil some minimum standards for safety, environmental impact etc. The building authorities do thus provide services for which it is in itself meaningful to apply a lean perspective and discuss waste, value and ‘leanness’. For the building authorities to provide high quality service, clarity and transparency regarding the project material (drawings, specifications, documentation etc.) is vital. Regardless of whether building authorities are considered as customers or as stakeholder(s), the issue is vital on a construction project level since the approval processes are of crucial importance to the progress of the individual project.

In relation to integrating design and construction processes from a lean perspective the role of the authorities is problematic. Building authorities represent a link in the supply chain, but in a number of respects this indispensable supplier (of approval) is very different from other suppliers:

- The authorities work under rules and procedures (e.g. laws and standing orders for administration on municipal or governmental level) that to a large extent are far beyond direct influence of both the construction project participants and the authorities themselves.
- In many places, building authorities cannot be actively involved in the actual development of design solutions. Dependent on the local rules, they are often not allowed to inform designers about what they are in fact willing to approve prior to the submission of a design developed and documented to a relatively detailed level. Under such systems authorities are thus limited to either approve or disapprove designs as submitted.
- Where many lean tools and procedures seek to apply a pull-based small batch approach to design and production processes, building authorities generally demand design and construction information to be submitted in relatively large batches through procedures that are essentially push-based.
- Typically codes, rules, and de facto approval criteria are to some extent interpretive (or by designers perceived as such). In the three case studies designers were faced with uncertainty regarding how codes would be interpreted in relation to the specific project, and regarding how different criteria and design factors would eventually be weighted against one another by the authorities. Some of this uncertainty derived from experiencing that
individual officers in charge of approval decisions in practice often interpreted and judged differently than their colleagues.

- Unlike other suppliers, the building authorities cannot be rejected or avoided and substituted with a different agency. The relations between authorities and the companies of the supply chain that are in fact (from the point of view adopted by the lean philosophy) adding value to facility client and users, are thus highly asymmetric. Thus the construction project organisations in fact have very limited possibilities for developing relations and procedures for the interaction with authorities, but may have to comply with circumstances as is.\(^{223}\)

- Holding the monopoly on indispensable services the building authorities serve the whole market without much possibility for affecting demand variability. The building authorities cannot refuse to accept more jobs if unable to match capacity with demand, and nor can they ‘subcontract’ approval work to other organisations in demand of jobs. In periods of high construction activity approval processes may thus be easily delayed and this may affect project planning and execution on the individual project level. Here a ‘domino effect’ may be triggered if delays at one project obstruct individual companies from carrying out timely transfer of capacity from one project to another.\(^{224}\)

It was evident from the case studies II and III that circumstances regarding the building authorities and their role strongly affected processes of design and production planning/preparation. Issues of authority approval were devoted much attention in discussions regarding design decisions. Important observations were that project participants perceived that the existing organisational framework was either non-optimal or directly inappropriate for delivering ‘value’ to building authorities and for achieving a smooth approval process. At one of the case projects (Case II, which had special organisational circumstances) design committee members perceived considerable problems in relation to the approval processes and found that the organisational framework surrounding these critical processes were inappropriate for project participants as well as for client and users, but also for the authorities.\(^{225}\) At one of the case projects (Case II) an authority representative voiced dissatisfaction

\(^{223}\) This thesis will restrict from discussing possibilities of indirect influence on building authorities approval processes. In practice very large companies and organised interest groups may often influence development of rules and procedures, e.g. through political influence, and in large parts of the world corruption and bribery is an inevitable element in the interaction between construction organisations and building authorities. Arguments of this thesis build the presumption of full compliance with laws and rules.

\(^{224}\) Currently this problem is experienced several places in Denmark where a boom in the construction business has made authorities’ approval process lengthy which often causes implications and delays for the individual construction project. – The phenomenon has been described in a recent article published in the Danish business newspaper Erhvervsbladet (April 24\(^{rd}\) 2006, pp. 1 & 7).

\(^{225}\) Case III from California provides another example of this perception among project participants. The lean coordinator of the client organisation went as far as to saying that if it had been possible to hire the building authorities for active participation in the processes of working out the building designs (before submission for approval) he would be willing to pay a very high price for being able to use their expertise and knowledge and values for the benefit of a better design with improved probability for smooth approval. His explicit analysis was that the individual project could then be executed with much improved ‘value delivery’ to the building authorities, which would, he believed, directly benefit the individual project through faster approval processes and through decreased uncertainty regarding approvals and thus improved scope for improving efficiency in both design and construction (conversation Oct. 14\(^{th}\) 2005). – See Chapter 6.
regarding the cooperation with the project delivery team, but the case studies did not show if the authorities (or their representatives) felt that the organisational framework constituted a problem in itself.
In Case III from California, feedback on detailed design had not yet been obtained from building authorities during the phases when the project was monitored. Project participants nevertheless emphasised very strongly their concerns regarding what they considered to be a very problematic framework for cooperating with the authorities. There appeared to be a full consensus among the construction professionals that existing structures and formalities did not benefit any of the parties including the authorities themselves (this view was also voiced by representatives of client and users). During meetings the design discussions often revolved around questions of obtaining approval or limiting the project’s exposure to risk deriving from uncertainty regarding the obtaining of authority approvals.

At both of these case projects (II & III) bureaucratic constraints regarding approval processes were found to affect processes of developing both the design and consequently also production process planning in ways that did not conform to the lean philosophy’s emphasis on customer orientation. - This without being of benefit to other stakeholders.

7.1.6. Discussion
The question of whether the lean philosophy provides a means which is appropriate for pursuing integration of design/construction processes is a question that cannot easily be answered with a simple ‘yes’ or a ‘no’.
From the discussion on the two main focus points of the lean philosophy - waste and customer value - six main findings stand out:

1. The lean philosophy is highly interpretative;
2. The lean philosophy is mainly concerned with processes and flows of processes, while many issues of organisational and economical character (e.g. financial management, financing, transaction cost aspects etc.) are not explicitly addressed;
3. The lean philosophy focuses on issues of customer value and waste-efficient production but does not directly address a large number of other issues such as e.g. profitability and risk management etc. that are themes of high importance to construction performance and construction project management;
4. In relation to the products provided by the construction industry, identification of ‘end customer value’ - and hence also of ‘waste’ – cannot in general be accurately and unambiguously done, which is of crucial importance for lean application since these parameters are the very focus points of the lean philosophy;
5. It was found that construction is embedded in a context where a number of factors, of which some are structural and others derive from the very nature of construction, prevent that the lean philosophy can immediately be fully and holistically applied to construction. – And;
6. Of the characteristics of a fully integrated construction delivery team, that were identified by Baiden et al. (2006)\textsuperscript{226}, several are not at all addressed by the lean philosophy.

\textsuperscript{226} See Chapter 3.
The conclusion to be drawn is that - at least on its own - the lean philosophy does not offer a fully appropriate means for pursuing integration of design and construction processes. However, the lean philosophy makes no claim of covering all management issues, and some of those not addressed do have significant importance in relation to practical initiatives for design/construction integration.\textsuperscript{227} This does not necessarily imply that the philosophy cannot be useful in relation to achieving design/construction integration. For evaluating if this is so, the following two questions will need to be answered:

a) Even if not fully practically applicable as a sufficient means for design/construction integration, can the lean philosophy at all be useful for the pursuing of design/construction integration? - And;

b) If so, to what extent and under what preconditions?

\textbf{a) Can the lean philosophy at all be useful for pursuing design/construction integration?}

On a fundamental level, the lean philosophy argues design/production integration, and a high extent of integration/coordination between design and production processes is arguably required if issues of waste and value are to be addressed in a wider system’s perspective.

The lean philosophy’s focus on value/waste parameters can – to the extent that ‘value’ is identified and understood – be functional as reference points that are common to construction project activities such as planning, organising, coordinating and decision making regarding both design and physical production. At one of the case projects (Case III) participants themselves evaluated and explicitly concluded that the lean philosophy’s value/waste focus had been practical as the basis for a framework of ideas for developing more integrated supply chain practices.

Case studies also revealed that, regardless of whether the term ‘value’ was used explicitly, collaborative design discussions addressing simultaneously functional, aesthetic, financial and technical views (incl. aspects of constructability and assembly strategies) often revolved around issues of value for customer/client and users and questions about how this should be interpreted (discussed above). On the level of design and construction concepts, principles and details, achieving consensus about specific value criteria from which to work was obviously important for project participants to collaboratively identify integrative solutions.

Such examples can be considered to constitute \textit{critical cases}\textsuperscript{228} for whether or not the lean philosophy can be useful for achieving design/construction integration. From the findings it can therefore be concluded that this is possible.

\textbf{b) To what extent useful and under what preconditions?}

The extent to which the lean philosophy can be useful in relation to pursuing design/construction integration is limited by a number of factors that have been

\textsuperscript{227} This should not be ignored, but elaborate examination of how the lean philosophy may correlate or conflict with the larger field of management issues must be left for future research. The discussion appears to be emerging and has been taken up by Koskela et al. (2004), Koskela & Ballard (2006) and Winch (2005; 2006). - See Chapter 3.

\textsuperscript{228} To confirm, challenge, or extend a theory there may exist a ‘critical’ case that meets the conditions for testing the theory and thus determines if its propositions are correct (Yin 1994, p. 38). For example, if a theory assumes that that it is not possible for a human being to grow taller than 2.80m a sample of 5,000,000 people that are all shorter than that will not prove that the theory is right. The appearance of just one man taller that 2.80 will, however, provide a critical case that proves the theory wrong.
elaborately discussed above: The lack of one specific single end customer; the
dynamic and ambiguous character of client/customer/stakeholder value; problems of
thoroughly identifying waste, etc.

For the answering of research question no. 2, a number of processes/methods/issues
critical for design/construction integration from a lean perspective have been
identified (discussed below). However, a thorough answer to the question, b), cannot
be provided as part of this research, and this task can arguably provide a relevant topic
for future research. Nevertheless, a few key findings help frame the further
examination of this field. The following themes were found to be important for
determining more accurately to what extent and under what preconditions the lean
philosophy can in practice provide a means useful for pursuing design/construction
integration:

- The level of abstraction applied;
- Time perspective;
- Limits to (sub)systems addressed, and;
- Organisational, social and cultural context of construction delivery.

In the following these four themes are discussed from the perspective of how they in
practice are likely to influence severely the degree of successful application of a lean-
based approach for design/construction integration. Either, in principle, as
consequences of applying the lean philosophy to construction with its contextual
peculiarities, or because of impeding effects deriving from a mismatch between
integrative lean approaches and the industry’s long established fragmentation, which
is embedded in business and company structures, in regulation, as well as in social
and cultural systems.

- **The level of abstraction applied:** The lean philosophy is highly interpretive
and the main ideas can be discussed at various levels of abstraction. The level
of abstraction significantly influences the general applicability of the lean
philosophy. As discussed above, it can be argued that the lack of one specific
end customer requesting perfectly specified value delivery, principally makes
the lean philosophy inapplicable to the larger construction design and
production system.

However, in the literature the philosophy has been described (often implicitly)
with reference to a different context\(^{229}\) and – if maintaining the fundamental
idea of customer focus - it can be argued that when interpreting the basic
philosophy for the construction context, the ‘end customer’ should be
understood in a much wider sense including also wider society (Koskela
2000). Though the concept of ‘customer’ remains ambiguous and to some
extent vague this considerably improves the scope for applying the lean
philosophy of enhancing value and eliminating/reducing what is not adding
value to construction customers (waste).

To conclude: If understood at a higher level of abstraction, where the
philosophy can be reduced to a general focus on enhancing value and reducing
waste, then ‘lean’ can be feasible for construction (and hence also for
construction design/production integration) only if adjusting to context the

\(^{229}\) Usually that of Japanese car manufacturing wherefrom ‘lean’ originated.
notion of ‘end customer’ that will need to represent several different stakeholders of which some are parties that are in principle external to the individual project.

On the other hand: if the lean philosophy is interpreted in terms of procedures, techniques and concrete strategies (as e.g. value stream mapping, just-in-time and pull logistics, small-batch production, etc.) the lean philosophy can, as argued by Koskela (1992), be applied to construction. However, if limiting focus to this narrow interpretation, one compromises the perhaps most central feature of the lean philosophy: the very system’s perspective as the basis for enhancing customer value while addressing waste. It also limits the potential benefits of the approach to the delivery of some product through an efficient process, while not distinguishing between whether the product in fact represents value or not. Still it may be an advantageous approach for integrating design/production for increasing efficiency on subsystem level (discussed below).

- **Time perspective:** As was discussed above, adopting a single moment in time as the reference for customer value is inappropriate for construction. Thus, if adopting without modification Womack & Jones’ (1996; 2003) definition of value together with its status as starting point for lean thinking, it follows that the philosophy is not viable for practical application as a basis for approaching the theme of design/construction integration.

However, if, as discussed under the bullet point above, fundamental concepts of the lean philosophy is (re)interpreted with respect to the construction context, it can be argued that the ‘value delivery’ should be interpreted with reference to a whole-life perspective. Uncertainty regarding future needs naturally provides a high degree of uncertainty regarding the value that will eventually be delivered. This complicates practical application of a lean approach and may easily limit the degree to which a lean project strategy (no different from other construction value delivery strategies) can be successfully applied. In comparison to many other products, built artefacts deliver their value over a very long-time horizon and considerable waste is generated through use phases and eventually through disassembly/removal/disposal. The time- and life-cycle perspective applied is therefore critical for achieving design/construction integration from a lean value/waste perspective.\(^{230}\)

- **Limits to the (sub)systems addressed:** In principle the lean philosophy advocates the application of a full system’s perspective. However, in practice there will, not least in a project-based industry, be some limits to how far this can be applied. To map and address the entire value stream, including related processes for all materials and supplies, is in practice impossible\(^ {231}\), and even

\(^{230}\) The importance of the time and life-cycle perspective in the context of construction has been discussed by Jaafari & Manivong (1999) arguing that construction project processes should be integrated from a life-cycle perspective.

\(^{231}\) To illustrate with one example, the value stream for structural steel starts already in the mines. A very large number of processes and operations follow before the steel itself has been produced from the raw materials after which it can be further processed into e.g. beams or columns that can be given surface treatment prior to storing, cutting, transportation, handling etc. before, finally, assembly on a construction site. – Application of an entire system’s view on a full construction project and its value streams will encompass millions of processes and operations, of which most are far beyond the limits of direct influence of the construction project organisation.
lean initiatives for integrating ‘only’ primary construction project activities of
design and production/assembly are in practice forced to significantly restrict
focus to a selection of the entire supply and value system.
The question regarding practical limits to which (sub)systems that can be
addressed (and how?) is highly interconnected to the wider organisational,
social and cultural context in which design/construction integration is to take
place (discussed below).

- **Organisational, structural, social and cultural context of construction
delivery:** If viewed on its own, the lean philosophy, that primarily addresses
aspects of technical product delivery processes, can be argued to represent a
technocratic approach that does not take into account structural factors (e.g.
regulation, professional boundaries, common agreements, monopolies etc.)
and social factors as e.g. institutionalism and culture. This is of significant
importance when seeking to apply the lean philosophy for integration
purposes.

As was discussed previously, structural factors cannot be ignored in relation to
any initiative of lean application and/or design/construction integration. A
characteristic of the construction profession is the extensive hierarchy of the
typical project organisation where not only different organisational ‘layers’ but
also company borders (and affiliated individual interests) contribute to a
pronounced fragmentation of the production process (Emmitt & Gorse 2003).
Construction has strong centuries old traditions for specialisation. In addition
to the division between design and production/assembly, subcontractors are
specialised in one trade discipline reflecting assignments typically tendered.
This specialisation and professional diversity (reflected already in the
educational structures) have led to increased fragmentation and problems with
communication between specialists (Emmitt 2002).

Logical reasoning suggests that it must be very difficult to de-fragment design
and construction beyond the extent to which the production can itself be de-
fragmented in terms of teams and processes. Unfortunately the addressing of
downstream fragmentation in the construction supply chain is an extremely
complex issue due to a considerable gap between the formal and the *de facto*
organisational project structures. Cooperation should take place as described
in the official organisation charts, but nevertheless cooperation and
communication follow systems and patterns very different from the formal
channels of command (Hill 1995). Organisations reflecting institutional rules
generally tend to build gaps between formal structures and actual work
activities (Meyer & Rowan 1977), and a classic study of construction site
production exposed no less than five *de facto* sub-organisations within
individual projects (Tavistock 1966).232

Research by e.g. Hill (1995), Pietroforte (1997), Stinchcombe (1959; 2001)
and Wild (2002) found formal construction project information and
communication to be incomplete and the informal communication paths

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232 1) a system of operations; 2) a system of resource controllers; 3) a system of formal controls
(directive functions); 4) a system of informal controls (adaptive functions), and; 5) a system of social
and personal relations.
crucial to project completion. To temporary organisations, as are typical in construction, the lack of an efficient formal communication network is highly problematic since social and interpersonal relations need to be (re-)established at every project. The combination of a newly composed temporary organisation and a large complex project is therefore likely to hamper effective coordination and control over the production process. Under such conditions institutionalised conceptions of ‘the way things are done’ may therefore often be advantageous (Powell 1991). Based on own studies of processes of building design and its subsequent realisation in production, Stinchcombe (2001) concluded that the formal organisation and procedures in fact worked.\textsuperscript{233} However, one important prerequisite for this was that in construction the “formality is being embedded in a system that fills in the blanks in the blueprint with formalities or informal competencies worked out elsewhere, especially in the institutions of the separate crafts.” (Stinchcombe 2001, p. 180). Put differently: Construction design and production processes are interwoven in complex mutually supportive structures of which some are formal and others informal.

The lack of transparency regarding essential project processes provides considerable difficulty for obtaining a full organisational overview of the individual construction project. This provides a severe challenge to applying to any larger extent the lean philosophy of organising for customer value enhancement and waste elimination. Achieving an integrated approach to design and construction phases requires a high degree of attention to the way design information is interpreted and used and to how this influences down-and upstream processes of coordination throughout the project organisation. In practice the very presence of institutionalised practices is likely to limit the momentum that can be established behind initiatives for design/construction integration. Organisations innovating in important structural ways bear considerable cost in legitimacy when deviating from prescriptions of institutional myths of how a responsible organisation is supposed to be structured and function (Meyer & Rowan 1977). Failure to effectively address these issues may imply considerable risk of the construction project organisation impeding the implementation of new process-orientated procedures (Jørgensen et al. 2004b; 2004c).

\textsuperscript{233} Stinchcombe’s studies were conducted in the USA. On the basis of studies from only one local environment it is difficult to conclude that the findings have universal validity. However, Stinchcombe discusses social mechanism on a very general level and the conclusions are substantiated with similar findings based on cases from other contexts different from construction, which suggests that a substantial degree of generalisation can be assumed.
Aspects of organisational culture\textsuperscript{234} are of significant importance in relation to implementing different project procedures in the construction industry. Previous research has illuminated how culture and subcultures in construction in fact challenges severely successful implementation of lean construction initiatives, even when of modest scope (Johansen \textit{et al.} 2004; Jørgensen \textit{et al.} 2004b; 2004c). In addition to subcultures between professions there appears to exist some degree of cultural division between construction designers and the downstream supply chain that complicates effective cooperation throughout the supply chain (Powell 2001).\textsuperscript{235}

Although an important factor, culture was not a specific focus point of the case studies. This theme was not given priority as it had previously been the subject of two publications\textsuperscript{236} that were based on studies from the very same contractor organisation as was studied in Case I and Case II.

To conclude: the specific organisational, social and cultural context of construction delivery, that widely defines the environment for practical application of the lean philosophy, is more than likely to greatly influence the extent to which the lean philosophy can be successfully applied in practice as a means for pursuing design/construction integration.

Despite that it is possible to identify a number of factors and mechanisms that all, in one way or another, influence directly the extent to which the lean philosophy can – in theory and/or in practice - be useful as a means for pursuing design/construction integration, it is from this research not possible to draw any firm and general conclusions as to their collective influence. This will in principle need to be examined at the level of the individual construction project where the specific lean initiative, client/user/stakeholder value, the systems addressed, and the various contextual factors can to a higher or lower degree of adequacy be assessed.

For such practical application it would be advantageous to have a model for determining how these many parameters will collectively limit the scope for (appropriate) lean initiatives for design/construction integration. However, such a model cannot be composed from the, as argued by Koskela (2000), yet incomplete

\textsuperscript{234} When approaching cultural phenomena it is important to define what we understand by the term ‘culture’ which is often used in various ways implying very different meanings. E.g. Kunda (1992) and Alvesson (2001) cite Geertz (1973) for defining organisational culture as: “the shared rules governing cognitive and affective aspects of membership in an organisation, and the means whereby they are expressed.” - It is important to distinguish between culture and social structures. Culture refers to kinds of common mentality of shared ideas, conceptions, meaning and symbols. Social structures refer to systems of action as deriving from social relations and interaction. As such culture is not a tangible phenomenon to be found and deduced from individual persons. Culture only exists between persons (Alvesson 2000, 2001). Consequently culture cannot be studied in its pure form independent from the context in which it manifests itself.

\textsuperscript{235} Management publications, not least those on the lean philosophy, often emphasise the importance of culture and recommend that ‘the right culture’ must be created in the organisation addressed. Generally speaking Alvesson (2001) warns against overestimating managers’ ability to consciously shape, control and change culture within the companies they run. Kunda (1992) delivers an illustrative example of the difficulties of achieving successful culture engineering exercises. His findings indicate that managers will not be able to properly see through the results of their actions when attempting to make constructive use of identity-building mechanisms. These views and findings differ radically from much popular management literature that ascribes top managers extensive opportunity to radically reengineer existing organisational culture.

\textsuperscript{236} (Jørgensen \textit{et al.} 2004b) and (Jørgensen \textit{et al.} 2004c).
understanding of design and production phenomena that are at present not satisfactorily explained in all detail. In other words: a model predicting accurately the collective implications of factors limiting the practical applicability of the lean philosophy for pursuit of design/construction integration cannot be composed since a general theory of production is missing. Koskela (2000) argued that a theory of production\(^{237}\) would need to encompass simultaneously three different views of production: production as a process of transformation, as a process of flows, and as a process of value generation, of which the perspective of value-generation is the less understood. As argued in this research, the inappropriate understanding of value-generation in construction is the primary factor limiting the applicability of the lean philosophy to the construction system’s perspective.

7.1.7. Conclusion

As a means for pursuing integration of design and construction processes the lean philosophy can be appropriate - though not on its own - provided that the notion of ‘end customer’ is redefined to represent a range of construction stakeholders including wider society, and provided that value is defined with reference to the whole-life perspective in which a built artefact delivers its value and generates waste.

In principle ambiguity, vagueness and uncertainty regarding value aspects define the limit to which the lean philosophy can be applied in an integrative construction project system’s perspective. From the perspective of practical application, wider contextual issues - including structural, social and cultural aspects - also contribute to considerable limitations regarding the extent to which lean philosophy can be applied as a means for design/production process integration.

In general, the application of the lean philosophy as a basis for design/construction integration is impeded by the absence of a general theory of production, which tends to support the conclusions of Koskela (2000).

7.2. Research question 2

Answering the second research question - Which processes and/or methods and/or issues are critical for integrating construction design and production from a perspective of the lean philosophy? – cannot be answered with a ‘yes’ or a ‘no’. To provide a thorough explanation about which processes and methods that are critical and which that are not, a general theory of production is needed (see above).

However, as was argued as part of the discussion on research question no. 1, it is possible to identify a number of aspects that do - in theory as well as in practice - influence and, to various extents, limit the applicability of the lean philosophy to construction, both on the more general level and also in relation to providing an appropriate means for design/construction integration.

Though it is not possible, on the basis of this research, to propose a general model describing their collective influence, the case studies revealed some issues that appeared to be influential in relation to integrating design/construction processes with reference to a lean perspective:

\(^{237}\) In Koskela’s terminology ‘production’ covers design processes and all other phases necessary for producing artefacts of value. Koskela (2000) argued that an adequate general theory of production would in principle be applicable to all sorts of artefact production, including construction.
7. Analysis and discussion

• Project value specification;
• Active client, user and stakeholder involvement;
• Decision and decision process transparency;
• Transparency regarding value/waste consequences of design decisions;
• Management of design iteration processes;
• Collaborative design with contractor/supplier involvement;
• Commitment from project participants (including suppliers);
• Project team learning.

These will be discussed from the perspective of processes and methods of practical construction project management.

This research cannot provide a complete list of all processes, methods and issues that in a given context and in a given situation may be of critical importance in the perspective of ‘lean’ design/construction integration. From the three case studies the eight themes listed above were found to encompass the aspects of most central importance. Many of these aspects are reflected in several of the eight themes that are in many respects overlapping. However, for the sake of clarity, they will be discussed individually though this procedure does entail some repetition.

7.2.1. Project value specification

One issue that has been emphasised in a large body of literature - and emphasised by e.g. Womack & Jones (1996; 2003) as the first step in applying a lean approach - is that of value specification. As argued in relation to research question no. 1 (see above), the degree to which value can be identified and specified principally defines a limit for the applicability of the lean philosophy.

While critical if applying a lean approach, the specification of aims and objectives (that should reflect client value) is in general of great importance to successful project execution (e.g. Hughes 1989; Lawson 1997; Emmitt 1999) and is not a particular feature of lean application to construction.

All three case studies clearly illustrated the importance of thoroughly specified client and stakeholder value(s) if efforts to systematically enhance value and eliminate waste are to be possible in a broader perspective encompassing both design and construction. In all three case projects the construction professionals, representing both design and production staff, spent much time discussing aspects of client/user/stakeholder value in relation to certain design and project decisions. Discussions either focused on understanding value as a prerequisite for a decision process or - when project participants found that they had sufficient understanding of the value aspects - how the potential decision outcomes should be assessed and compared in respect to the value parameters. Discussions revealed that it was not always sufficient for the construction professionals to be informed about a client/user preference. Understanding of the circumstances or assumptions behind a preference/wish/demand was often essential for the design teams to determine what would be the most advantageous decision in terms of value delivery when also considering the need to secure sufficient support from influential stakeholders.238

238 In general this issue is critical for value management as well as for successful project completion (Green 1994).

Bo Jørgensen (2006)
For a brief overview of the value specification aspects illustrated by the three case projects, see Table 7.2:

<table>
<thead>
<tr>
<th>Findings:</th>
<th>Case I:</th>
<th>Case II:</th>
<th>Case III:</th>
</tr>
</thead>
<tbody>
<tr>
<td>The entire value theme was, to some extent, intangible and difficult to come to grips with for the client, users and the construction professionals.</td>
<td>●</td>
<td>●</td>
<td>(●)</td>
</tr>
<tr>
<td>Value could not be sufficiently specified prior to commencing design, since value understanding to some extent derived from developing the design.</td>
<td></td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Client (and other stakeholder) value exhibited dynamic behaviour.</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Value specification was (also) a political process driven by different interests representing different degrees of influence.</td>
<td></td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Project participants found it difficult to interpret how different value aspects were prioritised in relation to others, and to see through if a value issue was in fact concerned with high customer value or if its specification was to some extent rhetorical.</td>
<td>(●)</td>
<td>●</td>
<td></td>
</tr>
<tr>
<td>Political processes did not end with the carrying of decision, and some stakeholders actively sought to change project course in their favour.</td>
<td></td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Project participants (including client representatives) considered risk of scope creep to be a serious challenge and constraint to efficient project management.</td>
<td></td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>‘Value’ served as a common reference point for designers and contractors when collaboratively seeking integrative solutions for design and assembly.</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
</tbody>
</table>

Table 7.2: Overview of main findings regarding project value specification.

7.2.1.1. Conclusion
Case findings suggested that specification of value must be made explicit, and if representing a compromise between different stakeholder interests the value specified must be sufficiently viable/supported to ensure the stability of decisions necessary for effective planning. The value specification process is likely to take significant time and effort,\(^\text{239}\) and it is necessary that the project delivery team, in addition to knowing

\(^{239}\) Discussed below, see "Management of design iteration processes 7.2.5".
what has been specified as value, understands the underlying factors and preconditions of individual stakeholder value, needs, interests etc. The ‘political arena’ of the different stakeholder interests and the power/influence backing them must be understood by the project management and delivery team.

7.2.2. Active client, user and stakeholder involvement

With customer value in focus, the lean philosophy requires effective identification of the value parameters (argued above). This cannot be done in isolation from ‘the customers’.

As generally recognised in construction management literature, effective involvement of clients and stakeholders is a critical factor to successful project completion. The case studies illustrated that the role and active involvement of stakeholders is of central importance to practical efforts of applying a lean perspective to integrating design and construction. Very often information or response from client/stakeholders was a critical factor for progressing with project decisions of importance for design/construction integration. All three case studies showed that this information was not always easy for the design teams to get.

Of particular importance from a lean perspective is that late project changes easily result in significant waste and may compromise value delivery when comparing to what could have been achieved had the needs/wishes prompting the change been known or anticipated at earlier stages. Active client involvement and meticulous briefing process is necessary for limiting the risks of such changes.

Some key findings relating to this theme are illustrated in Table 7.3:

<table>
<thead>
<tr>
<th>Findings:</th>
<th>Case I:</th>
<th>Case II:</th>
<th>Case III:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Effective communication with client and stakeholders was necessary for judging in value-related design questions.</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Project delivery teams found it difficult to achieve the necessary feedback from client, users and other key stakeholders.</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Lack of certainty regarding client and key stakeholder positions were commonly an obstacle for planning and decision-making.</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>During the project, stakeholders and project participants learned and gradually developed deeper understanding of project objectives and value.</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Process facilitation (formal or informal) was an important factor in supporting efficient communication and collaboration.</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Clients and other stakeholders had difficulties seeing through</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
</tbody>
</table>

---

240 See e.g. (Brandon & Powell 1984); (Green 1994); (Lawson 1997); (Hughes 1989); (London & Kenley 1999); (Emmitt 1999); (Cooper et al. 2003); (Emmitt & Gorse 2003); (Whelton 2004); (Jensen 2005).
the wider project consequences of individual design decisions, which was why some degree of continuous client/stakeholder involvement in design phases was critical.

Client and stakeholders’ expectations regarding the project developed differently from those of the construction professionals.

(Late) project changes impeded lean strategies and hampered design/construction integration.

Table 7.3: Overview of main findings regarding involvement of client, users and other stakeholders.

7.2.2.1. Conclusion
For a significant part of the construction project, active and continuous involvement of client and stakeholders is critical for achieving an integrative approach to design and construction in respect to enhancing value and eliminating waste.

7.2.3. Decision and decision process transparency
The sequence of decisions is an important issue in any project work. In construction this theme is a key issue on several levels, not least when pursuing an integrated approach to design and construction project phases. Information generated in ‘upstream’ project processes is decisive to the specification, planning and execution of downstream activities, and there is significant interdependence between subsystems where decisions regarding one system influence design and assembly processes of other systems. Establishing transparency regarding the wider consequences of individual project decisions and their effects on downstream issues and activities is an important requisite for project and information management, especially when seeking an integrative approach to design and construction processes.

In the perspective of enabling a systematic approach to enhance value delivery and eliminate waste, the three case projects emphasised the importance of structuring and managing the project for achieving an appropriate match between decision/approval processes and design progress. A particular challenge, it seemed, was to ensure that decisions and decision processes would appear sufficiently transparent to client, users and other stakeholders, especially those that were not construction professionals. This commonly created difficulties when previously fixed decisions were challenged by some project parties.

Some key findings relating to this theme are illustrated in Table 7.4:

<table>
<thead>
<tr>
<th>Findings:</th>
<th>Case I:</th>
<th>Case II:</th>
<th>Case III:</th>
</tr>
</thead>
<tbody>
<tr>
<td>The structuring of design work and decisions was crucial for the design team’s possibilities for pursuing a lean approach to design/construction integration.</td>
<td>◎</td>
<td>◎</td>
<td>◎</td>
</tr>
<tr>
<td>Integrative lean approaches were challenged by the lack of a shared understanding about what information that would be needed at what stages and about</td>
<td>◎</td>
<td>◎</td>
<td></td>
</tr>
</tbody>
</table>
when decisions would need to be fixed.

Lack of shared understanding about the decision sequences brought turbulence in the project progress and disrupted some of the project teams’ integrative delivery strategies.

Design management was challenged by the lack of sufficiently common understanding of what it meant that certain decision were fixed and of what other parameters would, in consequence, be effected.

Especially regarding the client, users and other non-construction professional stakeholders, project management often failed to establish a sufficient understanding of the decision processes and of the limitations that specific decisions would bring to the project.

Disagreements about who should have the final say on certain project and/or design decisions.

Lack of organisational transparency regarding the project to some extent obscured decision processes concerning critical issues.

Table 7.4: Overview of main findings regarding transparency of decisions and decision processes.

7.2.3.1. Conclusion
Establishing transparency regarding decisions, decision processes and their wider consequences (e.g. in terms of impacting the liberty of choice regarding decisions in later project stages) is a critical factor when pursuing an integrative approach to design and construction from a lean perspective of systematic value/waste optimisation. It is of high importance to ensure that transparency is achieved also from the perspective of client, users and other stakeholders directly involved. The structuring of the overall project and its individual phases to secure sufficient transparency is critical for enabling a lean approach to design/construction integration.

7.2.4. Transparency regarding value/waste consequences of design decisions
This theme is closely connected to the previous regarding decision and decision process transparency. To systematically address value/waste aspects in the systems’ perspective it is necessary to establish transparency regarding the wider consequences of design decisions. A specific challenge was achieving efficient cost feedback at early stages of the design process. One of the conclusions of case project III, where a ‘design to target cost’ methodology was applied, was that efficient cost feedback required a great level of detail in the design, which demanded increased work intensification in early design phases.
Some key findings relating to this theme are illustrated in Table 7.5:

<table>
<thead>
<tr>
<th>Findings</th>
<th>Case I</th>
<th>Case II</th>
<th>Case III</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regarding specific design decisions, suppliers (incl. speciality contractors) often identified waste consequences unanticipated by designers.</td>
<td></td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>The higher the level of design detail in early project phases, the more discussion among project participants about how to achieve the most value/waste optimal solution.</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Efficient cost feedback required a high level of detail in the design process.</td>
<td></td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Often difficult to get sufficient feedback regarding value/waste consequences that decisions concerning one subsystem would have on another.</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>The impact of upstream design decisions on downstream processes was often not realised until considerably later in the process.</td>
<td></td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Contractors/suppliers often possessed knowledge of how specific details could be modified for improved value delivery.</td>
<td></td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Aspects of constructability and transparency regarding value/waste consequences of design decisions appeared to be interconnected.</td>
<td></td>
<td>●</td>
<td>●</td>
</tr>
</tbody>
</table>

Table 7.5: Overview of main findings regarding transparency of value/waste consequences of design decisions.

7.2.4.1. Conclusion
Establishing transparency regarding the wider value/waste consequences of design decisions is critical for achieving design/construction integration from a lean perspective. Especially two findings stand out as central: That efficient contractor/supplier feedback often requires a high level of detail in the preliminary design, and that contractor/supplier knowledge and engagement contributed to both the improving of client/customer/stakeholder value delivery and to the addressing of waste aspects related to later project stages.

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241 This does not necessarily imply that effective feedback cannot be achieved before late design stages when basic parameters are fixed, but (as was illustrated in Case project III) that considerable parts of the design will need to be worked through early in the process when it is still possibilities to use the feedback for altering design concepts without violating design intent (see Jørgensen 2005).
7.2.5. Management of design iteration processes

From the perspective of the lean philosophy design iteration processes is arguably a crucial theme, not least when seeking an integrative approach to design and construction. From the value/waste understanding of the lean philosophy, design iteration will generate a lot of waste through drafting, rework, examining possibilities never pursued etc. This waste is difficult to categorise as either ‘Type 1’ or ‘Type 2’ waste. One can argue that such waste can in principle be eliminated if designers ‘get it right’ in the first attempt and that design iteration thus generates ‘Type 2 waste’. However, if acknowledging that iteration and learning processes are absolutely necessary for generating sufficient understanding of customer value aspects (see below), project purpose and value specification, and to achieve design solutions that enables project delivery to meet those through an efficient production process, then much of this waste should be considered ‘Type 1 waste’. Hence the question does not become one of minimising resources spent on design but (in principle) to manage design to deliver best possible value through project processes generating less possible waste over the system’s perspective. An important issue of lean design management is thus to enhance positive iteration while avoiding negative iteration (i.e. iteration that does not contribute to solutions and that could have been avoided). Ballard (2000c) proposes four strategies and a number of techniques for avoiding negative iteration.

Some findings from the case are illustrated in Table 7.6:

<table>
<thead>
<tr>
<th>Findings:</th>
<th>Case I:</th>
<th>Case II:</th>
<th>Case III:</th>
</tr>
</thead>
<tbody>
<tr>
<td>In relation to customer value, improvements were added to</td>
<td>(●)</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>the conceptual during the iteration processes of</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>developing the detailed design.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Design iteration processes provided, according to</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

---

242 See Chapter 3 for introduction to ‘Type 1’ and ‘Type 2’ waste.
243 The system’s perspective can be defined in relation to a single project or a series or portfolio of projects where some extra resources spent on one project can be considered an investment for the benefit of performance on subsequent activities. Set-based design strategies are commonly suggested in literature on lean design/product development (e.g. Cooper & Slagmulder 1997; 1999).
244 This issue has been discussed in a number of publications focusing on lean issues. Some examples are: (Cooper & Slagmulder 1997; 1999); (Koskela et al. 1997); (Tzortzopoulos & Formoso 1999); (Ballard 2000c; 2002); (Hammond et al. 2000); (Formoso et al. 2002c); (Freire & Alarcón 2002); (Choo et al. 2004).
245 These are:

- Restructure the design process:
  - Use DSM (design structure matrix) to resequence
  - Use pull scheduling to reduce batch sizes and achieve greater concurrency
- Reorganise the design process:
  - Make cross functional teams the organizational unit
  - Use team problem solving (call a meeting)
  - Share ranges of acceptable solutions
- Change how the design process is managed:
  - Pursue a least commitment strategy
  - Defer this decision (defer commitment)
  - Practice set-based design
  - Use the Last Planner System of Production Control
- Overdesign (design redundancy) when all else fails.”
Bo Jørgensen (2006)

Table 7.6: Overview of main findings regarding management of design iteration processes.

7.2.5.1. Conclusion
In short, it appeared that the two most fundamental aspect of managing design iteration is to enable positive design iteration on value delivery while preventing negative iteration, and to ensure that crucial parameters are not fixed too early to preclude positive improvements. Yet it is necessary to make sure that parameters and specifications are fixed sufficiently early for the design and project progress to be efficiently managed. - Obviously a balance that must be found.

Design iteration processes are strongly connected to (and widely influenced by) issues and aspects of several other themes such as those of value specification, collaboration, learning, client/user/stakeholder involvement, commitment, and decision transparency (several of which that are also influenced by the design iteration processes). In the perspective of design/construction integration, and of achieving high customer value through waste-efficient project delivery, the management of design iteration processes is a key issue.

7.2.6. Collaborative design with contractor/supplier involvement
Collaborative working between designers and contractors/suppliers is obviously a key element in design/construction integration. Collaborative working is a very wide theme which involves a large number of issues. The mere sharing of information, which appears to commonly be mistaken for ‘collaborative design’, is but one of them. In addition to various aspects of coordination, collaborative design often bear implications such as the need for project participants to change their usual ways of working in order to enable effective interaction with other parties.\textsuperscript{246} When applying a

\textsuperscript{246} Such changes may by project participants be perceived as rather dramatic and difficult to handle. Designers often have their own preferred approaches to the design process (e.g. Jones 1992; Lawson 1997) that may need to give way to other approaches to enable active supplier involvement. Collaborative design may also bear elements of participants needing to give up previous ‘monopoles’
perspective of design/construction integration from a lean approach the case studies illuminated a number of issues that are summarised in Table 7.7:

<table>
<thead>
<tr>
<th>Findings:</th>
<th>Case I:</th>
<th>Case II:</th>
<th>Case III:</th>
</tr>
</thead>
<tbody>
<tr>
<td>During collaborative design exercises project participants representing contractors and other suppliers generally engaged as strongly as architects, other designers and client representatives in discussions on enhancing value delivery.</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>‘Value’ served as a common reference point for designers and contractors when collaboratively seeking integrative solutions for design and assembly.</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Contractor ideas/strategies for procurement and assembly served as input for design processes, and as output of collaborative iteration.</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Customer value, constructability, risk and costs appeared to be the central parameters around which much of the collaborative design discussions revolved.</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Commonly difficult for non-designers to see through the design processes.</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>It was commonly difficult for contractors/suppliers to see through how their area of project involvement would be affected by decisions regarding other project parts.</td>
<td></td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>A high level of detail in design was often necessary for achieving efficient contractor feedback.</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Difficulties of ensuring efficient information sharing between different project parties.</td>
<td>(●)</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Project participants commonly experienced that ‘information overload’ challenged identification of the aspects on which their input/feedback was needed.</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Clear leadership and process facilitation.</td>
<td>(●)</td>
<td>(●)</td>
<td>●</td>
</tr>
<tr>
<td>Collaborative approaches to integrating design and construc-</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
</tbody>
</table>

and allow room for intervention in the ‘domain’ of others. Issues that are not unlikely to be followed by considerable organisational and sociological implications.
tion processes were often impeded by absence of necessary client decisions/feedback and/or clarity regarding public approval.

Table 7.7: Overview of main findings regarding collaborative design with supplier/contractor involvement.

7.2.6.1. Conclusion

For achieving the sufficiently high degree of effective collaboration necessary to address value and waste issues in the wider project perspective, it requires considerable effort from project participants to involve actively in a large number of project processes - some regarding aspects of which individual participants’ area of responsibility may be only marginally and indirectly affected. Case studies showed that effective collaborative design was challenged by difficulties of ensuring sufficient supplier feedback, and that this often required a high level of design detail in early project phases. Facilitation and leadership appeared to be crucial issues, not least for achieving effective communication between the construction professionals and other stakeholders as e.g. users.

7.2.7. Commitment from project participants (including suppliers)

A lean approach to design/construction integration requires active collaboration which requires commitment from project participants. For addressing value and waste in a wider perspective and for avoiding sub- or point optimisation, commitment from the supply chain commitment is a necessity, not least in an organisationally and technically complex production as construction. The entire theme of achieving supply chain commitment is beyond this thesis, but some important findings regarding commitment issues were deducted from the three case studies (see Table 7.8):

<table>
<thead>
<tr>
<th>Findings</th>
<th>Case I:</th>
<th>Case II:</th>
<th>Case III:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project participants considered the risk of insufficient commit-</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>ment from one or more project parties a threat to successful project</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>execution through a lean approach.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The lean approach to design/construction integration was to some</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>extent compromised as a result of some parties (e.g. public authorities)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>not engaging/participating in working from new/different procedures.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lack of sufficient incentive prevented a key supplier from involving</td>
<td>●</td>
<td></td>
<td></td>
</tr>
<tr>
<td>which thus forced a reduction of ambition</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Absence of sufficient trust among some project participants impeded</td>
<td>(●)</td>
<td>●</td>
<td></td>
</tr>
<tr>
<td>the integrative lean approach.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 7.8: Overview of main findings regarding commitment project from participants.

247 See Chapter 3.
7.2.7.1. Conclusion
Engagement from the supply chain is a vital element in efforts of applying the lean philosophy as a means for design/construction integration. The case projects showed that the lack of engagement from individual organisations/project participants was a significant impediment to the strategies applied. It was strongly indicated that the issue of commitment is of central importance to the wider theme of design/construction integration.

7.2.8. Project team learning
Continues improvement, systematic experimentation and continuous learning on all organisational and technical levels are important aspects of the lean philosophy and the production systems from which it developed (see Chapter 3). The importance of learning processes for successful project performance in construction (like other industries) has long been recognised and discussed in literature.248 Already at pre-project stages learning processes are influential in shaping project circumstances. From research into design brief processes and its management challenges Whelton (2004) concludes that continuous learning processes are vital for the outcome of the individual project, and draws attention to the importance of managing and facilitating the processes of purpose development among various stakeholders.
All three case projects displayed some findings regarding learning and team learning (see Table 7.9):

<table>
<thead>
<tr>
<th>Findings:</th>
<th>Case I:</th>
<th>Case II:</th>
<th>Case III:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Learning processes gradually developed the project participants’ understanding of the project purpose, customer value issues and possible solutions.</td>
<td></td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Some learning processes appeared to take place in the interaction between different project participants and important stakeholders, whereby the parties involved learned about the project as well as about how to collectively deliver it.</td>
<td></td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Learning was explicitly an important part of the lean-based project delivery strategy.</td>
<td>●</td>
<td></td>
<td>●</td>
</tr>
<tr>
<td>In discussions of how to proceed with specific issues, project participants on their own initiative brought up the issue of what had been learned through the project</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Learning-focused process facilitation widely applied.</td>
<td>(●)</td>
<td></td>
<td>●</td>
</tr>
<tr>
<td>Project participants themselves found that learning processes had led to performance improvement during the project.</td>
<td></td>
<td></td>
<td>●</td>
</tr>
</tbody>
</table>

Table 7.9: Overview of main findings regarding project team learning.

---

248 Examples are (Lawson 1997); (Schön 1998); (Emmitt 1999); (Emmitt & Gorse 2003).
7.2.8.1. Conclusion

Learning and team learning is an important element for systematic lean application. The opportunity to discuss value via the lean-based project delivery strategy helped to stimulate exchanges of information/knowledge and thus enabled learning to take place.

7.2.9. Discussion

Eight themes have been identified as being of more or less essential importance to pursuing design/construction integration from the value/waste perspective of the lean philosophy: project value specification; active client, user and stakeholder involvement; decision and decision process transparency; transparency regarding value/waste consequences of design decisions; management of design iteration processes; collaborative design with contractor/supplier involvement; commitment from project participants, and; project team learning.

There is considerable overlap between the findings regarding the eight themes that widely draw attention to the importance of a number of general and basic project management issues. Almost all of the case findings somehow relate back to the need for the following issues to be managed efficiently:

- Establishing and specifying value(s), aims and objectives that are known and understood by all project participants and that have the support necessary to remain sufficiently stable to enable efficient value/waste-focused project management.
- Establishing transparency of the project in terms of organisation, the interests represented, power and influence relations, and of participant and stakeholder positions;
- Establishing transparency regarding the project progress and chronology, decision-making, time limits, deadlines (e.g. for when certain information will be needed), design freeze, handoffs etc.;
- Securing efficient communication and exchange of information at, and between, all project levels;
- Securing continuously effective client/user/stakeholder involvement, information and feedback;
- Securing sufficient commitment from all central project participants and stakeholders;
- Facilitation of inter-organisational and interpersonal communication processes and of collaborative working;
- Project planning and structuring for matching decision processes with the need for positive iteration, and to ensure the delivering of project and design information when needed for downstream processes (‘pull’);
- Establishing transparency of value/waste and cost consequences of project and design decisions;
- Establish a project framework with structures and incentives supporting that project delivery can be executed under conformance with the above criteria.

These are processes and/or methods that appeared to be of fundamental importance when pursuing an integrated approach to design and construction from the perspective of a lean philosophy.
These findings are of a very general character and it is worth noticing that previous research into drivers of construction project failures has resulted in similar findings. In his doctoral research into the relation between construction design management and project failure, Meland (2000) concludes that communication and planning are the working methods most central to avoid project failure. Based on a large survey from the Norwegian construction sector Meland identified a number of factors strongly affecting the risk for project failure that could be classified as belonging to two cause variables: insufficient client support, and insufficient design management. The general conclusion was that too little time and other resources are available for construction design - a general circumstance that was identified as a major cause of project failure. Similarly the case studies of this research (especially Case III) drew attention to the need for investing significant resources and efforts in design phases for obtaining effective feedback from downstream contractors/suppliers and for achieving a high degree of design/construction integration.

7.2.10. Conclusion

The findings of this research can be summarised under a few processes/methods that were found to be of crucial importance for integrating design and construction from a perspective of the lean philosophy:

- **Value identification, specification and communication:**
  - Achieving a common understanding of customer value, needs etc. and securing that they have the support necessary for project continuity.

- **Establishing an appropriate project delivery framework:**
  - Establishing incentives, agreements, resources (incl. time, financial means, and human and organisational resources), contracts etc.

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249 Meland defines project failure from seven ‘failure criteria’: 1) excess of investment budget; 2) excess of budget; 3) non-conformance with client performance indicators; 4) insufficient user satisfaction with the facility delivered; 5) client dissatisfaction with the facility delivered; 6) insufficient quality of drawing material and timely delivery of drawings to construction site, and; 7) project participants’ dissatisfaction with the project in terms of overall project outcome and/or the course of events.

250 Meland’s survey supported the assumption that design/construction integration is likely to be an important factor for successful project completion, but Meland’s studies did not approach the integration theme as representing an aim in its own right. Important findings were that failure drivers deriving from insufficient client support were: insufficiently tight time limits for design assignments; insufficient financial resources for design work, and; lack of clarity regarding roles and responsibilities. Failure drivers from insufficient design management were: lack of management competences by the design manager; insufficient communication; insufficient definition of aims and objectives, and; insufficient planning by the design committee.

251 One important difference when comparing the results of this research with those found by Meland is the importance ascribed the setting of aims and objectives, which Meland found to be of less significant importance, while the three case studies of this research all identified this issue to be of critical importance. The reason for this deviation appears to be different perspectives on ‘successful’ project delivery. Meland studied drivers of failure in relation to client satisfaction/expectation regarding a few tangible and easily measurable criteria. This thesis focuses on integration as an objective and approaches this theme from the perspective of the lean philosophy’s focus on enhancing customer value and eliminating/reducing waste, which in principle goes much further than the mere fulfilling of client expectations and ‘hard’ quantifiable project objectives. When considering this, Meland’s conclusions regarding drivers of project failure seem to support the findings of this research’s identification of processes and methods crucial for lean design/construction integration.
supporting design/construction integration and an overall lean approach.

- Project organisation and the structuring and planning of delivery processes:
  - Composition of delivery team and its organisation, and project scheduling, planning and preparation processes.

- Establishing transparency:
  - Of organisation, decision-making, technical issues, and of value/waste consequences.

- Management and leadership:
  - Management of project and project related processes, incl. active involvement of project stakeholders.

- Learning:
  - Supporting and stimulating learning, team learning and exchange of knowledge at all levels of project processes and at all relevant levels of the organisations involved.

The findings can be organised according to whether client-side or project delivery team (of which the client might be an important party) in principle is in position to ensure effective management of these processes and methods. Graphically the findings can be illustrated through Figure 7.5.
Figure 7.5: Issues, processes and methods crucial to integration of construction design and production from a perspective of the lean philosophy.
Chapter 8

Conclusions and reflections
8. Conclusions and reflections

The research set out to study

- RQ 1: if the lean philosophy is appropriate as a means for pursuing integration of construction design and production processes, and;
- RQ 2: which processes and/or methods and/or issues are crucial or critical for integrating construction design and production from a perspective of the lean philosophy.

This chapter will summarise the conclusions of the research and reflect on the findings in relation to further work of practice and research into application of lean approaches to design/construction integration.

8.1. Research question 1

Regarding the first research question it was concluded that as a means for pursuing integration of design and construction processes the lean philosophy can be appropriate - though not on its own - provided that the notion of ‘end customer’ is redefined to represent a range of construction stakeholders including wider society, and provided that value is defined with reference to the whole-life perspective in which a built artefact delivers its value and generates waste.

In principle ambiguity, vagueness and uncertainty regarding value aspects define the limit to which the lean philosophy can be applied in an integrative construction project system’s perspective. From the perspective of practical application, wider contextual issues - including structural, social and cultural aspects - also contribute to considerable limitations regarding the extent to which lean philosophy can be applied as a means for design/production process integration.

In general, the application of the lean philosophy as a basis for design/construction integration is impeded by the absence of a general theory of production, which tends to support the conclusions of Koskela (2000).

8.2. Research question 2

The findings of this research can be summarised under a few processes/methods that were found to be of crucial importance for integrating design and construction from a perspective of the lean philosophy:

- Value identification, specification and communication:
  - Achieving a common understanding of customer value, needs etc. and securing that they have the support necessary for project continuity.

- Establishing an appropriate project delivery framework:
  - Establishing incentives, agreements, resources (incl. time, financial means, and human and organisational resources), contracts etc. supporting design/construction integration and an overall lean approach.

- Project organisation and the structuring and planning of delivery processes:
  - Composition of delivery team and its organisation, and project scheduling, planning and preparation processes.
8. Conclusions and reflections

- Establishing transparency:
  - Of organisation, decision-making, technical issues, and of value/waste consequences.

- Management and leadership:
  - Management of project and project related processes, incl. active involvement of project stakeholders.

- Learning:
  - Supporting and stimulating learning, team learning and exchange of knowledge at all levels of project processes and at all relevant levels of the organisations involved.

The findings can be organised according to whether client-side or project delivery team (of which the client might be an important party) in principle is in position to ensure effective management of these processes and methods. Graphically the findings can be illustrated through Figure 8.1.
8. Conclusions and reflections

8.3. Reflections on conclusions – thoughts on future research

The research set out to contribute with knowledge and insight for the ongoing construction management debate on the implementation of lean approaches to the built environment and how to pursue a higher degree of integration between construction design and production. Three years after the research project started in 2003 the topic is still high on the agenda of the current construction debate in Denmark, and abroad, and it is thus relevant to end this thesis with a few brief reflections on the completed research project.

8.3.1. The contribution of this research

The research did answer the research questions it set out to, but in the larger perspective of the construction debate its main contribution may, however, be the literature review on previous publications on the ‘lean’ theme (see Chapter 3). As the review illustrated, application of the lean philosophy to construction is a theme which is difficult to approach since the theme is very broad and at the same time
characterised by a high degree of interpretability, vague or missing definitions in key literature, and by the absence of a shared understanding of concepts and terminology for practical application, research and debate. However, the field is developing and ‘lean’ is receiving more attention in leading construction research journals. Critical debate is emerging, which can be seen as an indication that the lean theme is maturing and becoming established in the wider construction debate in terms of both practice and research. This thesis provides a comprehensive, thorough, and current analysis of the field. As such it provides researchers with a solid foundation on which to build future research. It is the hope of the author that the present work will contribute to this process and to future work on clarifying and structuring the debate on ‘lean’ in relation to construction.

8.3.2. Implications for practice
From the perspective of the construction practitioner considering a lean approach to pursue a strategy of design/construction integration, an essential question concerns the limitations of the lean philosophy.

An important argument of this thesis is that although the lean philosophy may be useful as a means for pursuing design/construction integration this should not be taken for granted. Appropriateness depends on the interpretation of the lean philosophy, and since the lean philosophy does not address all issues of vital importance to practical initiatives for design/construction integration, as a means for this purpose it is insufficient if approached in isolation.

Another important argument was that if interpreting the lean philosophy and approach literally as represented by the entire set of systems, procedures and management policies advocated by the books of Ohno (1988) and Shingo (1988) - titles that have been very influential in shaping the lean debate for manufacturing as well as for construction – the considerable gaps between prescriptions/recommendations and the conditions for implementation in the western built environment context suggest that ‘lean’ does not represent an applicable recipe for construction design and production. This thesis argues that the lean philosophy should be interpreted and understood in terms of its basic ideas and re-interpreted if transferred to a different context, such as construction. This is a key issue for work with lean application in construction since experiences and outcomes of lean implementation (positive and negative) cannot be generalised across business sectors. Context must be considered before drawing conclusions regarding a specific situation. An important implication of this conclusion is that the negative side effects on HR conditions that have been documented as an outcome of lean implementation in the motor vehicle industry do not necessarily transfer to construction.

The thesis has also argued that if pursuing design/construction integration from a point of departure in the lean philosophy, a whole-life-perspective should be applied if the key issues, enhancement of value and elimination/reduction of waste, are to be effectively addressed. This may, however, contradict the interests of key parties that may represent driving forces behind initiatives for integration since these parties are not unlikely to be motivated by short-term objectives of faster and cheaper project delivery while a ‘lean’ strategy of whole-life perspective on value/waste performance may be considered as less opportune (e.g. by contractors).
The research revealed a number of other aspects highly relevant for practical application of a lean approach to design/construction integration. Context is emphasised as representing factors of decisive influence for lean application, and the findings highlighted the importance of addressing early project and design phases for achieving an effective collaborative approach for dealing with value/waste issues. This has considerable implications in relation to common practices that, in different ways, influence substantially the construction project delivery framework. Some obvious examples are: price-based procedures of competitive tendering (e.g. through design-bid-build arrangements) and the use of architectural competitions for defining a conceptual design. Both examples exclude possibilities for later design phases to be completed under full collaborative pursuit of value enhancement and waste elimination/reduction.

Another important issue which was highlighted by the case studies (Case II & III) was the importance of approval processes and how obstacles to actively involve the public building authorities in working from process-orientated procedures of lean initiatives provided a significant constraint for the project teams to collaboratively work in accordance with their intentions.

Arguably the wider questions regarding the specific project delivery framework and its implications for lean application and integrative approaches deserve more attention in research and debate.

8.3.3. Reflections on method and the limitations of the research

This research was conducted through a qualitative approach to three case studies. A critical reflection could be that the lean philosophy was weakly represented in the approaches found at the two case studies from Denmark, Case I and in particular Case II. As mentioned in Chapter 2, the case projects were chosen from the simple criteria that they were the only accessible cases where the lean theme was at all applied, although, in the Danish cases, rhetorically more than substantially. Nevertheless, these cases probably represented some of the most thorough lean application that could be found in the Danish construction industry in 2003-2004.

A further weakness of the case studies was that, because of unforeseen events, they could not be studied from start to completion. The case studies resulted in numerous findings and it would have been relevant to deepen the research with empirical material from production phases. This research did not have possibilities for very detailed ethnographic studies of complete project phases, but it highlighted that many contextual and technical aspects are highly influential in relation to lean application in general as well as in relation to design/construction. This is an important finding in relation to future research in this field.

For future research into design/construction integration under the lean theme it will be a significant advantage if sufficient time is available for studying full project cycles. However, this demands considerable resources from the researchers and long-term commitment from the construction project team.

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252 This was a misfortunate consequence of Case project I becoming postponed for long periods whereby the original intention of studying the entire project cycle from design to completion had to be modified (see Chapter 2 and Chapter 4).
If integrative lean approaches are becoming widely adopted throughout all major construction project phases it will also be relevant to consider perspectives in identifying some key indicators that may be instrumental for conducting surveys/studies addressing the wider industry. In this respect systematic collection of quantitative data enabling cross-project comparisons and/or performance development studies over time, would be valuable.

8.3.4. Suggestions for future research

In terms of future research, three themes stood out from the analysis and discussion (Chapter 7) as pivotal in relation applying the lean perspective to construction:

- Whole-life value and waste identification;
- Transparency regarding value/waste consequences of project and design decisions, and;
- Project delivery framework supporting lean application.

8.3.4.1. Whole-life value and waste identification

For effectively applying the lean philosophy to construction and addressing the two lean focus areas of enhancing value and eliminating/reducing waste, a whole life-approach must be adopted. The ability to identify value and waste factors over the very long perspective - over which constructed facilities typically deliver their value and generate a considerable proportion of waste - provides a significant challenge and constitutes a limiting factor to the extent to which the lean philosophy can be applied to the construction system’s perspective. Regarding lean application to the built environment it must thus be recognised there is a need for developing a better understanding of drivers of value and waste from the whole-life perspective. This is, in itself, a very large field of research and encompasses several important issues, each worthy as topics for future research.

The most essential questions regard:

- Practical methods for identifying elements and drivers of value and waste from the whole-life perspective of a built facility.
- Long-term approaches to value and waste aspects involve significant uncertainty, why there is a need for improved methods to assess aspects of probabilities, uncertainties and risks in relation to the setting of a value delivery strategy for developing appropriate design concepts.

8.3.4.2. Transparency of value/waste consequences of project and design decisions

A related theme, revealed by the case studies, highlighted how practical application of a lean approach to the full project perspective is complicated by difficulties of seeing through the wider value/waste consequences of project and design decisions. Collaborative design was useful in this respect, but it did not fully solve the problem that project participants or other stakeholders often failed to identify when a decision regarding one issue would later affect others. Practical methods for establishing transparency regarding the entire value/waste consequences of project and design decisions will significantly increase the extent to which a lean strategy of optimising value/waste performance can be pursued.
8. Conclusions and reflections

8.3.4.3. Project delivery framework supporting a lean approach

The lean philosophy advocates an uncompromising focus on enhancing end customer value while eliminating/reducing waste. The wider framework for project delivery is crucial for successful application of a lean approach, and the case studies illustrated that lack of conformance between the (organisational) project framework and lean strategies can significantly challenge the scope for application of the lean philosophy throughout all project delivery phases. A hitherto neglected theme of the lean design/construction debate regards the role and influence of building authorities and approval procedures that case studies highlighted as very influential in relation to establishing lean project procedures.

Some central issues for research to address are:

- Possibilities, methods and principles for establishing incentives, contracts, partnerships etc. that support an overall lean approach for project delivery.
- Possibilities and methods for involving building approval authorities in the - within the achievable - most feasible manner regarding the entire (lean) project delivery process.
- Possibilities and methods for redefining the practical role of building approval authorities from the perspective of establishing conformance between approval procedures and an integrated lean approach to design and production processes while ensuring (and possibly improving) that approval processes serve their purpose.
- Effective stakeholder involvement throughout all project delivery phases.
References
9. References


9. References


*Bygningslov for Staden København, af 12. April 1889.*


Bo Jørgensen (2006)


9. References


Bo Jørgensen (2006)


Appendices
10. Appendices

**Appendix 1**
Questionnaire 1, Case II: *Early phases of the collaborative design* (Autumn 2004).

**Appendix 2**
Questionnaire 2, Case II: *Half way through detailed design* (Autumn/winter 2004-2005).

**Appendix 3**
Questionnaire 1, Case III: *Target Value Design*.

**Appendix 4**
Outline for semi-structured group interview, Case III.
**Appendix 1**

**Spørgsmål vedr. projekteringssamarbejdet**

*På en skala fra 1 til 5 (hvor 5 svarer til det mest tilfredsstillende).*

**Kommunikation**

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<tr>
<th>Vurdering: (1-5)</th>
<th>Eventuel bemærkning: (fortsæt evt. på bagsiden af skemaet)</th>
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- **Hvor tilfredsstillende har du under opstarten af projekteringsforløbet oplevet kommunikationens omfang?**

- **Hvor åben synes du kommunikationen har været?**

**Samarbejdspartnernes motivation**

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<th>Vurdering: (1-5)</th>
<th>Eventuel bemærkning: (fortsæt evt. på bagsiden af skemaet)</th>
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- **I hvor høj grad synes du, at dine samarbejdspartnere er motiverede til at udføre deres del af de opgaver, som I arbejder sammen om?**

**Indbyrdes faglig respekt**

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- **Hvor meget respekt har I haft for forskellige faglige tilgange?**

**Samarbejdspartnernes hensyn til andre**

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<th>Vurdering:</th>
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I hvor høj grad har du oplevet at dine samarbejdspartnere har taget hensyn til andres målsætninger og ønsker i deres handlinger?

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<th>Vurdering: (1-5)</th>
<th>Eventuel bemærkning: (fortsæt evt. på bagsiden af skemaet)</th>
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**Fælles diskussion**

I hvor høj grad har I i fællesskab diskuteret en beslutning (eksempelvis m. henblik på at lokalisere alternativer og konsekvenser) før den træffes?

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<th>Vurdering: (1-5)</th>
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**Fælles beslutninger**

I hvor høj grad er beslutninger truffet i fællesskab?

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**Tilfredsstillende beslutninger**

I hvor høj grad er du selv tilfreds med de beslutninger, som er blevet truffet?

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**Samarbejdspartneres viden og evner**

I hvor høj grad synes du at dine samarbejdspartnere har den viden og
de evner der skal til for at udføre deres del af de opgaver, som I arbejder sammen om?

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<th>Konfliktløsning</th>
<th>Vurdering: (1-5)</th>
<th>Eventuel bemærkning: (fortsæt evt. på bagsiden af skemaet)</th>
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<td>Hvis konflikter er opstået i de samarbejdsrelationer du er en del af, i hvor høj grad har I så været i stand til at løse dem?</td>
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### Spørgsmål vedr. byggesagens videre forløb

#### Forventninger

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<th>Hvorimod retter du dine mest positive forventninger til den forestående byggesag? (nævn op til tre punkter):</th>
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**Udfordringer**

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<td>Hvad forventer du bliver byggesagens største tekniske udfordring?:</td>
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<td>Hvad forventer du bliver byggesagens største organisatoriske udfordring?:</td>
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### Spørgsmål vedr. projekteringssamarbejdet

_På en skala fra 1 til 5 (hvor 5 svarer til det mest tilfredsstillende),_

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<th><strong>Kommunikation</strong></th>
<th>Vurdering: (1-5)</th>
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<tr>
<td>Hvor tilfredsstillende har du under projekteringssforløbet oplevet kommunikationens omfang?</td>
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<th><strong>Samarbejdspartnernes motivation</strong></th>
<th>Vurdering: (1-5)</th>
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<tr>
<td>I hvor høj grad synes du, at dine samarbejdspartnere har været motiverede til at udføre deres del af de opgaver, som I arbejder sammen om?</td>
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<th><strong>Indbyrdes faglig respekt</strong></th>
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<tr>
<td>Hvor meget respekt har I haft for forskellige faglige tilgange?</td>
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<th><strong>Samarbejdspartnernes hensyn til andre</strong></th>
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<th>Tilfredsstillende beslutninger</th>
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<td>I hvor høj grad er du selv tilfreds med de beslutninger, som er blevet truffet?</td>
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<td>I hvor høj grad synes du at dine samarbejdspartnere har haft den viden og de evner der skulle til for at udføre deres del af de opgaver, som I arbejder sammen om?</td>
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<th>Projekteringsforløbet i fht. dine oprindelige forventninger</th>
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<td>Har et eller flere forhold under det hidtige projekteringsforløb overrasket dig <strong>positivt</strong>?:</td>
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<td>Har et eller flere forhold under det hidtige projekteringsforløb overrasket dig <strong>negativt</strong>?:</td>
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### Spørgsmål vedr. byggesagens videre forløb

**Forventninger til det forestående arbejde**

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<th>Hvorimod retter du på nuværende tidspunkt dine mest positive forventninger til den forestående byggesag? (nævn op til tre punkter):</th>
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<th>Hvorimod retter du på nuværende tidspunkt dine mest skeptiske forventninger til den forestående byggesag? (nævn op til tre punkter):</th>
<th>Eventuel bemærkning</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.</td>
<td></td>
</tr>
<tr>
<td>5.</td>
<td></td>
</tr>
<tr>
<td>6.</td>
<td></td>
</tr>
</tbody>
</table>

**Udfordringer**

<table>
<thead>
<tr>
<th>På baggrund af projekteringsforløbet, hvad forventer du bliver byggesagens største tekniske udfordring?:</th>
<th>Eventuel bemærkning</th>
</tr>
</thead>
</table>

<p>| På baggrund af projekteringsforløbet, hvad forventer du bliver byggesagens største organisatoriske udfordring?: | Eventuel bemærkning |</p>
<table>
<thead>
<tr>
<th>Dato:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Navn:</td>
<td></td>
</tr>
<tr>
<td>Profession og rolle i projektet:</td>
<td></td>
</tr>
<tr>
<td>Firma:</td>
<td></td>
</tr>
</tbody>
</table>
Anonymous participation

FYI: All participants will remain anonymous and the answers dealt with in confidence. At a later stage a number of project participants will be contacted with requests for interviews. Participation is of course voluntary and wishes not to take part will be respected.

About the questionnaire

Survey questions are divided into two groups. The first group of questions targets the project collaboration process up to now. The second group of questions regards the future phases of the ARC project. Answering the questions does not require lengthy considerations. More important is your immediate reaction to the questions.

Questions regarding the design process cooperation

On a scale from 1 to 5 (where 5 represents the highest degree of satisfaction),

<table>
<thead>
<tr>
<th>Communication</th>
<th>Estimate: (1-5)</th>
<th>Remarks:</th>
</tr>
</thead>
<tbody>
<tr>
<td>How satisfactory did you perceive communication and coordination during the early design phases?</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Estimate: (1-5)</th>
<th>Remarks:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>How &quot;open&quot; have you found the communication to be?</th>
<th>Estimate: (1-5)</th>
<th>Remarks:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Which project issues have you found were dealt with through the most satisfactory process of communication? (mention up to three issues):</th>
<th>Remarks:</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.</td>
<td></td>
</tr>
<tr>
<td>8.</td>
<td></td>
</tr>
<tr>
<td>9.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Which project issues have you found were dealt with through the less satisfactory process of communication? (mention up to three issues):</th>
<th>Remarks:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>
1. Project partners' motivation

<table>
<thead>
<tr>
<th>Estimate</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1-5)</td>
<td></td>
</tr>
</tbody>
</table>

To what extent have you found the other project participants to appear motivated for doing their part of the tasks that you are collaborating about?

2. Mutual professional respect

<table>
<thead>
<tr>
<th>Estimate</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1-5)</td>
<td></td>
</tr>
</tbody>
</table>

How respectful have you and the other project participants been in relation to each other’s different professional and disciplinary approaches to the project?

3. Considerate action

<table>
<thead>
<tr>
<th>Estimate</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1-5)</td>
<td></td>
</tr>
</tbody>
</table>

To what extent have you experienced that the other participants have acted considerately regarding other participants’ aims and wishes?

4. Shared discussion

<table>
<thead>
<tr>
<th>Estimate</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1-5)</td>
<td></td>
</tr>
</tbody>
</table>

To what extent have the project participants collaboratively discussed decisions (e.g. to identify alternatives and consequences) before these were decided?

5. Collaborative decision making

<table>
<thead>
<tr>
<th>Estimate</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1-5)</td>
<td></td>
</tr>
</tbody>
</table>

To what extent have decisions been made by the participants collectively?

6. Satisfactory decisions

<table>
<thead>
<tr>
<th>Estimate</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1-5)</td>
<td></td>
</tr>
</tbody>
</table>

To what degree are you satisfied with the decisions made during the time of your involvement in the project?
Collaboration partners' knowledge and capabilities

<table>
<thead>
<tr>
<th>Estimate: (1-5)</th>
<th>Remarks:</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>To which degree do you find that the other project participants possess the knowledge and capabilities required for successful accomplishment of their part of the work you are doing together?</strong></td>
<td></td>
</tr>
</tbody>
</table>

Conflict resolution

<table>
<thead>
<tr>
<th>Estimate: (1-5)</th>
<th>Remarks:</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>To what extent have the participants managed to resolve conflicts experienced in their work?</strong></td>
<td></td>
</tr>
</tbody>
</table>

Questions regarding the future phases of the ARC project

**Expectations**

| Remarks: |
|----------------|----------|
| **Which are your most positive expectations regarding the future phases of the ARC project? (mention up to three issues):** |
| 1. |
| 2. |
| 3. |

**Which are your most skeptical expectations regarding the phases of the ARC project? (mention up to three issues):**

| Remarks: |
|----------------|----------|
| 7. |
| 8. |
| 9. |

**Challenges**

| Remarks: |
|----------------|----------|
| **Which issue do you expect will provide the biggest technical challenge in the ARC project?** |

| Remarks: |
|----------------|----------|
| **Which issue do you expect will provide the biggest organizational challenge in the ARC project?** |
### Questions regarding the target costing exercise

<table>
<thead>
<tr>
<th>Estimate: (1-5)</th>
<th>Remarks:</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>To what extent have you found the target costing exercise useful for preparing efficient execution of the tasks that you are responsible for?</strong></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Estimate: (1-5)</th>
<th>Remarks:</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>To what extent is it your impression that the target costing exercise has been useful for preparing efficient execution of tasks that fall within other project participants’ area of responsibility?</strong></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Estimate: (1-5)</th>
<th>Remarks:</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>To what extent do you find the established cost targets realistic and appropriate?</strong></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Estimate: (1-5)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>To what extent do you expect your company to make a satisfactory return on the ARC project?</strong></td>
</tr>
</tbody>
</table>

**Please specify the project factors you expect to have the most positive influence on your financial return on the ARC project:** *(mention up to three)*

<table>
<thead>
<tr>
<th>Remarks:</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
</tr>
<tr>
<td>2.</td>
</tr>
<tr>
<td>3.</td>
</tr>
</tbody>
</table>

**Please specify the project factors you expect to have the most negative influence on your financial return on the ARC project:** *(mention up to three)*

<table>
<thead>
<tr>
<th>Remarks:</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
</tr>
<tr>
<td>2.</td>
</tr>
<tr>
<td>3.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>YES</th>
<th>NO</th>
<th>Remarks:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Have you brought up these issues during the project meetings?** *(please mark)*

<table>
<thead>
<tr>
<th>Estimate: (1-5)</th>
<th>Remarks:</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>To what extent do you expect the other project</strong></td>
<td></td>
</tr>
</tbody>
</table>

282
participants to earn satisfactory returns on the ARC project:

Where do you see the biggest potential *advantages* in the application of target costing exercises to building design and project planning? *(mention up to three aspects):*

<table>
<thead>
<tr>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
</tr>
<tr>
<td>2.</td>
</tr>
<tr>
<td>3.</td>
</tr>
</tbody>
</table>

Where do you see the biggest potential *disadvantages* in the application of target costing exercises to building design and project planning? *(mention up to three aspects):*

<table>
<thead>
<tr>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
</tr>
<tr>
<td>2.</td>
</tr>
<tr>
<td>3.</td>
</tr>
</tbody>
</table>

Date

Name:

Email address:

Profession and role in the ARC project:

Company:
Appendix 4

Outline for group interview

*Presentation of PhD project*

**Questions / focus points for interviews and process mapping exercise**

It is often heard that project costs escalate dramatically through design development.

- Why’s that
- What could be done about it?

*How – in your own words – would you describe the lean initiative?*

*How – in your own words – would you describe target value design?*

*Do you get the feedback you need during this procedure?*

Do other participants get the feedback they need from you?

- How / why (not)?

*Can you describe your initial expectations to the process of target value design?*

*Have there been sufficient time for the target value design exercise (and design + review in general)?*

*Does the lean initiative and target value design lead to improved design/construction coordination?*

- How / why (not)?
- How can the method be improved? (or what would it take to make it work?)
- Is it possible to somehow use the method for reaching better cost/value trade-off, speeding up project progress or otherwise benefit?
Can you mention examples of successes and failures?

At the ARC project some costs occasionally developed differently than expected
- Why?
- How could it have been avoided?

Compared to other projects, how much time do you invest in participating in the target value design process?
- Does it pay off for you and your work?
- Does it pay off for others’ work?
- Anyone not benefiting?
- Does it pay off for the project at large? (who benefits the most?)
- Do you, all in all, find that your time is well spent?

Why is the client doing it? – What's the agenda?

Have the client managed to create sufficient win-win situations?

If there are major problems with the method, are they due to the method itself or due to the way the method/project is managed?

What is your background:
- Profession
- Role in project
- How are your incentives (salary/bonus etc.) linked to the project performance?
- Previous experience with collaborative design, lean and target costing?