INTERIORITY - a prefab case study

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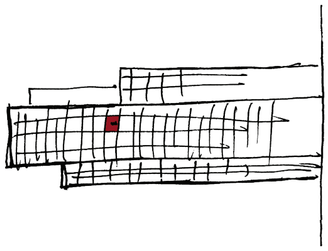

INTERIORITY
Volume 2: a prefab case study

PhD thesis submitted for assessment at the Doctoral School of Planning and Development,
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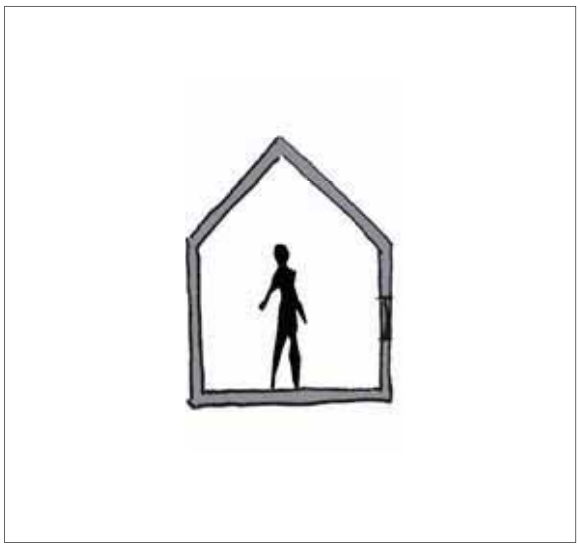


Domestic architectural quality?

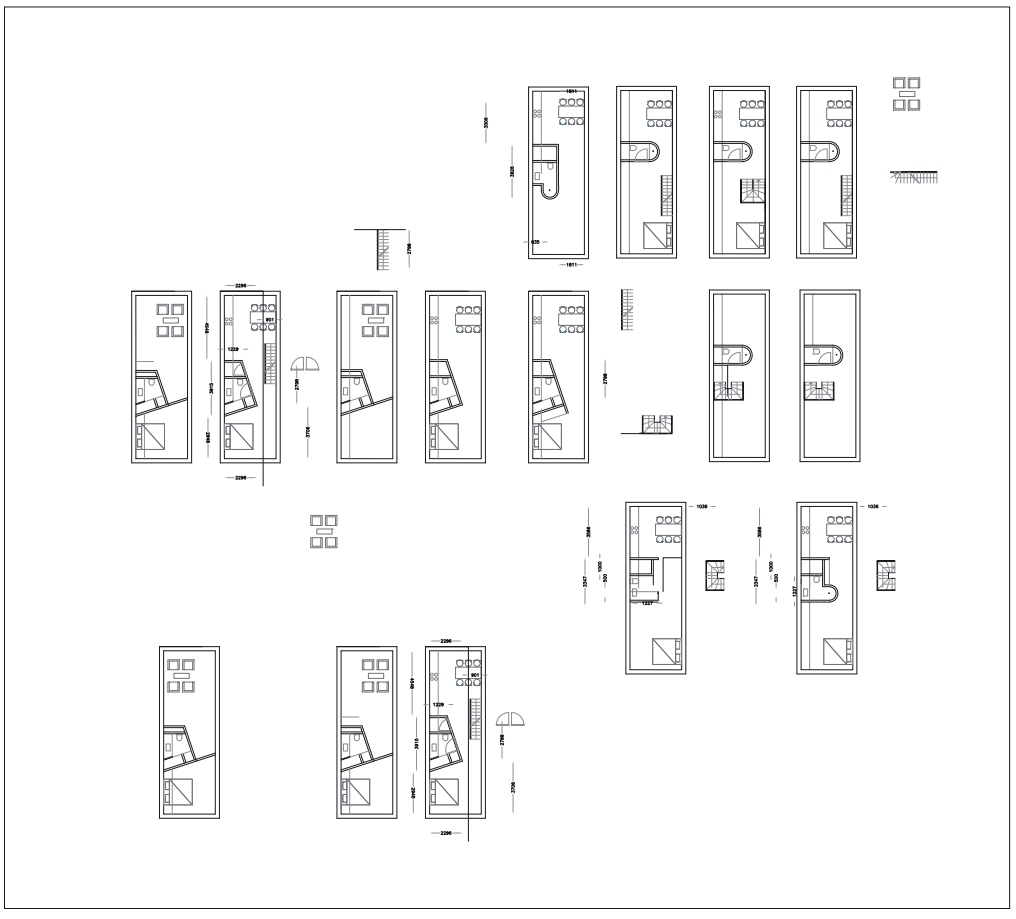
PREFACE

ARCHITECTURAL RESEARCH, it is my observation, represents a potential to pursue an elaboration on the inscrutable ways of architecture, the passions and emotions which eventually signify its quality and the complexity which define the relation between its theory and practice. It is this potential which has motivated me to go into research rather than to pursue a position in practice directly after having finished my Master's thesis in 2007. Hence, this choice was motivated by a desire to approach rather than to detach myself from practice and driven by a belief that research can help improve our ability as architects to communicate and to mediate within the complex multidisciplinary context characterizing our practice. In continuation of the theory development contained within the first volume, this second volume of my PhD thesis '*Interiority*' concerned with domestic architectural quality, consequently discusses this relation between architectural theory and practice through an engagement with the prefabricated house as a particular case study. Hence, as a case for pursuing actual application of the critical architectural theory of *interiority* developed in the first volume.

The subject of the prefabricated dwelling; that of utilizing production technical systems to develop an effective fabrication of homes brings the matter of domestic architectural quality to a head which fascinates me, and which has motivated the choice to include prefabrication as a case study in my research. On the one hand the Modern idea of the prefabricated house springs from a democratic vision of improving the quality and economy of the ordinary dwelling, however, on the other hand its practical revelation has proved a persistent challenge in which especially the spatial quality of these houses is still often compromised. Over a century after the Modern dream of the fabricated house was first envisioned, as accounted for by Colin Davis, Andreas Vogler, Bryan Burkhart and Allison Arieff, there are still economical, spatial and technical challenges to be overcome, before these dreams can be realized (Davies 2005, Vogler 2005, Arieff, Burkhart 2003). Rather than unfolding increased domestic architectural qualities, the fabricated house has in general remained architecturally uniform and poor in spatial and material detailing, often experienced as raw constructive frameworks rather than sensuous and spatially inviting homes (Arieff, Burkhart 2003 p. 9). Domestic architecture in general and the prefabricated house in particular unfold an area of architecture which is increasingly overlooked in the search for great cultural and urban commissions as discussed in Volume 1. However, the dwelling is also an area of architecture which, as accounted for continuously by architectural theoreticians and especially loud by Le Corbusier, contain the seeds for understanding general, even universal, architectural principles and which therefore seemingly condition the architectural task in general and which we therefore need to continuously reconsider (Corbusier 2000; 1923, Corbusier 1991; 1931). In continuation hereof my interest in the subject of domestic architectural quality as the main topic of my PhD research and the inclusion of prefabrication as a particular case study is twofold: On the one hand that of theoretically articulating the spatial principles of domestic architectural quality unfolded in the first theoretical volume of the thesis and on the other that of approaching practical means for applying and revealing these principles within domestic architectural practice unfolded within this second volume dealing with prefabrication as a particular case study.

As a point of departure I have approached the prefabricated house with an immediate critique in mind, a wish to critically asses our role as architects in the context of domestic architecture and most importantly that of pursuing a repositioning and articulation of the architectural question of the necessary quality of the home herein. Especially the prefabricated house often wind up spatially poor, it was and still is my claim, and these houses are consequently often experienced as raw constructive frameworks rather than intimate and inviting homes as stated above. Personally I associate an intimacy with the idea of the home, an intimacy which it is my observation finds its emanation in the furnishing details of the house; in its ability to approach the human body in a furnishing of places to sit, eat, sleep, bathe etc. I remember curling up in such corners and it is my perception that such spaces which are almost furniture allow for overview as well as for contemplation. As an architect I have begun to critically search for arguments which can explain the quality of such details which form a boundary layer in between envelope and furniture and which I find missing in the spatial poverty characterizing many of our contemporary spaces, especially the domestic ones. The result of this critical theoretical research approach has been the development of a particular interior approach to domestic architecture, the identification of domestic architectural quality with the notion of *interiority* as the ability of the spatial envelope itself to address the sensuous scale of furniture in an approaching of the human body. This development of *interiority,* as a critical architectural theory of domestic architecture in general, has been treated in the first volume of this PhD thesis, whereas this second volume treats the above mentioned attempt to apply this theory within the particular case study of the prefabricated dwelling. Theoretically this positioning of *interiority* as an expression of domestic architectural quality has pointed out the need to pursue a tectonic revelation of this ability of the envelope to address the sensuous scale of furniture directly within the structural and economical elements of the construct itself as concluded in Chapter 6 of the first volume. It is this particular potential which this case study concerning the fabricated dwelling addresses. The cooperation with the Danish housing manufacturer Boel Living A/S, who has also partly funded the research, has formed the specific point of departure which has given me an immeasurable opportunity to continuously pursue test and application of the theory developed through an actual engagement with practice, which I am extremely grateful for.

Within the general research field of domestic architectural quality I have found that this utilization of prefabrication as a case study has enabled an



Sketches; familiarizing with the prefabricated ‘box’.

articulation of the general threshold unfolded by architecture as a discipline, namely that of architectural space conceived as an aesthetic art form or as a technique. Whereas I am of the conviction that architecture emanates from and ultimately finds its justification in its functional, emotional and ultimately aesthetic ability to 'move' us as accounted for in the theory development. The encounter with the practice of the fabricated house at Boel Living A/S has also pinpointed the need for us as architects to improve our abilities to understand and to engage with the complex multidisciplinary and economical context signifying its technique. During the PhD research I have published a number of papers which exemplify and address this threshold in terms of the constructive technique of the joint itself, the multidisciplinary co operations characterizing prefab practice, and the conditions for articulating the interior ability of architecture to 'move' us herein. This volume presents and evaluates a selection of these papers each of which addresses the relation between architectural theory and practice which it has been a particular wish for me to approach through my research.

Reading guide

This volume is the second of two related parts forming the PhD thesis '*Interiority*', concerned with domestic architectural quality. At a general level the thesis takes its point of departure in the continuous and increasing need to improve our capability as architects to theoretically articulate this intangible concept of quality and to reveal it through an involvement with the complex multidisciplinary economical and constructive processes governing architectural practice. The PhD project has been developed in cooperation with the Danish prefab housing manufacturer Boel Living A/S, offering a unique opportunity to pursue application and documentation of the research through an actual confrontation with the particular practice of prefabrication as a case study within the general research theme; domestic architectural quality. This cooperation has been the starting point for pursuing a methodological linking of theory and practice, through a number of research loops, moving from theory development to practical application and vice versa. Thus, where the first part concerned the development of a general theoretical understanding of domestic architectural quality, this second volume concerns the particular case study pursuing application of this general theory within the context of prefabricated housing. Hence the theoretical part of the thesis can be read independently of the case study unfolded here, but the case study relies upon the theory developed in the first volume.

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Chapter 1

INTRODUCTION

FROM THE ORIGINS OF civilization we have been shaping our surroundings in order to form places in which to dwell. With the continuous expansion of our urban developments, the use of technology and management of construction processes has become a subject of increasing importance. In continuation hereof it has always been endeavored to develop construction systems through which to effectively fabricate constructions. Already during the colonial settlements prefabricated system deliveries were highly developed and shipped around the world. In America the use of prefabricated constructions were an integrated part of new settlements, in Sweden wood frame houses were developed as prefabricated systems long before the industrial revolution, and for three hundred years Palladio's and other renowned architects' villas were reproduced as types for effective and systematic reproduction through the use of Pattern Books in Great Britain (Davies 2005 p. 117). With the transition into an industrialized society in the 1850's the subject of utilizing the newly developed technologies became also an architectural and democratic vision of improving the quality and economy of the ordinary dwelling. In many ways the image of Henry Ford's assembly line manifested this vision; consequently we began to dream of the prefabricated house as argued by Herbert (Herbert 1984).

In continuation hereof industrialization and prefabrication within the building industry has been a continuous topic since the dawn of the industrialized society and it is still a heavily debated subject amongst engineers, manufacturers and architects. In the Modernist era architects were highly involved in the development of housing typologies suitable for mass-production. Le Corbusier, Frank Lloyd Wright, Rudolph Schindler, Walther Gropius, Charles and Ray Eames, and in the Danish context Arne Jacobsen and Jørn Utzon, have all been engaged with the subject of providing good quality low cost housing for the masses inspired by the automotive and aeronautical industries (Bergdoll, Christensen 2008). This vision of utilizing technological breakthroughs in the development of an effective fabrication of houses has today become probably even more relevant due to the ever increasing need for affordable dwellings (Davies 2005). Thus, even though the modern idea of the prefabricated house has also continuously, and with justice, been the subject of critique for its lacking spatial qualities it has been a field of continuous reengagement and strong beliefs in the possibilities of technology. Also within recent years a number of manufacturers and architects have reengaged with the subject of the prefabricated house. However, as it has been the case since the emergence of the prefab dream, these initiatives seems to still often strand in a number of spatially interesting prototypes to be forgotten in the eventual product, where the units set into production have continuously become only a shadow of the many architecturally iconic and expensive prototypes developed such as Buckminster Fuller's Dymaxion house (Davies 2005 p.11). It has been a continuous struggle of the prefabricated house to fulfill the dream of an economic home of a high architectural quality, however, rather than fulfilling the dream it has become an invective which the users still have difficulties finding faith in.

The belief in and dream of the prefabricated house has, however, survived and is even flourishing as an architectural field of its own, as publications such as full colored reference works like 'PreFabNow' and 'Prefab Design' witness (Trulove, Cha 2007, Minguet 2006). Within recent years especially the development of CAD/CAM, CNC-milling and other IT supported technologies have spawned new faith in the development of the prefabricated house as argued in Salvador Pérez Arroyo's reference work 'Emerging Technologies and Housing Prototypes', in Stephen Kieran and James Timberlake's 'Refabricating Architecture – How Manufacturing Methodologies Are Poised to Transform Building Construction' and in Daniel Schodek, Martin Brechthold, Kimo Griggs, Kenneth Martin Kao, Marco Steinberg's 'Digital Design And Manufacturing, CAD/CAM Applications in Architecture and Design'(Pérez Arroyo, Atena & Kebel 2007, Kieran, Timberlake 2004, Schodek 2004). These technologies, which theoretically make it possible to mass-customize rather than mass-produce, as it was the original vision of the prefabricated house, represent new architectural potentials and have so far resulted in a number of spatial experiments including highly organic and dynamic structures. Greg Lynn's 'Embryological House', Dagmar Richter's 'Dom-in(f)o' of 1999 and 2004 are examples hereof (Lynn 1999, Richter 2004). However, a general application and exploitation of these technologies seems to be preconditioned by a critical articulation of the subject of the task itself, namely the discussion of the spatial needs of the home, and a positioning of these needs in relation to the technological wonders as argued by Michael Hensel (Hensel, Menges & Hight 2009). It is my observation that a parallel can be drawn between the fascination of the assembly line of the early 20th century and today's fascination with digital technologies. Given the fact that there are still economical, architectural, as well as technical challenges to be overcome in order to realize the dream of the architectural and societal dream of the fabricated house as originally envisioned by Le Corbusier and Walther Gropius among others, it is consequently difficult to imagine that technology itself contains the answer. First and foremost it is my observation that a detailed discussion of the actual spatial qualities signifying a home is often absent in this fascination of technological breakthroughs and herein also the particular spatial potentials which they open up. Rather the idea of the fabricated house has often been accompanied by an architectural disclaim of responsibility in which the promises of technology have been translated into a strive for spatial flexibility and user involvement of which Walther Gropius and Adolf Meyer's 'Baukasten' project of 1922 was one of the first examples (Bergdoll, Christensen 2008). This idea of flexibility and user involvement is sympathetic but has often resulted in architectural dissociation with the question of the necessary spatial quality of these houses which has consequently often failed. Supplying for example only the exterior

Prototype of Arne Jacobsen's 'Kubeflex' prefab house consisting of cubic volume-elements designed in 1971.

framework and leaving the positioning of interior walls to the inhabitants themselves, as we have seen in early projects such as Walther Gropius and Konrad Wachsmann's 'General Panel System' which I will return to later, and in more recent ones of which 'Pærehaven' in Denmark is an example of. However, the user's have found this endeavored flexibility difficult to exploit, as it has also been the result in many earlier projects (Bergdoll, Christensen 2008 p. 80-85, Mortensen, Welling & Livø 2005 p. 12-13). It is consequently my observation that this endeavored flexibility affiliated with the envisioning of the prefabricated house has been a continuous hindrance in developing the actual architectural sensuous and spatial potential of these technologies and that this belief in flexibility can be found paralleled in the current belief in mass customization. The ability to create interesting and intimate spatial relations by uniting artistic architectural intuition with the necessary technical system and economy of construction often seems to be lost in the search for solutions that satisfy all parties of the project. Rather the result is often a spatial uniformity in which the constructive prefab modules define the spaces in which the kitchen is experienced like the living room which is experienced like the kids' room, and thus *interiority* is lost it is my claim in referring to the theoretical studies in Volume 1. Thus, at a general level the idea of a fabricated house raises functional and emotional architectural challenges and there is definitely an urgent need to position the question of how to spatially define the home within this context as suggested also in Volume 1.

However, also from a constructive and technical point of view the idea of a systematic production of houses has proved to be a challenge, and at a general level the idea of an assembly line house has proved a lot more complicated than that of the car. Not only is this challenge conceptual, related to distrust in the value and quality of the prefabricated house as stated above. As it can be witnessed in Gilbert Herbert's account for Konrad Wachsmann's year-long search for the solution to the perfect constructive joint, which he believed would simultaneously contain the solution to the system of the prefabricated house, caused him to seemingly lose track of its architectural value as a home (Herbert 1984). It seems that often, the constructive challenges related to the physical realization of the prefabricated house, have posed significant challenges in themselves. In opposition to the car chassis which can be formed and welded together into one continuous piece, more often than not the scale of the house necessarily causes it to be divided into a number of modules, for example planar wall floor and roof elements or complete volume elements, which are to be assembled on site. Often the complexity of joints and tolerances in the assembly of these modules have made the prefabricated houses even more expensive than traditional construction, which is indeed a paradox also accounted for by Andreas Vogler, Mark Anderson, Allison Arieff and Bryan Burkhart (Vogler 2005, Arieff, Burkhart 2003, Anderson, Anderson 2007). Often we have consequently been left with prefab constructions which are neither homes nor effective production systems: As opposed to the car which has a specific form that can be intriguing and even become a part of our identity, the prefabricated house has more often than not ended out without characteristics, without spatial invitations and details allowing us to functionally and emotionally move in and let the house become a part of our identity. Hence when seen in relation to the general critique of the state of domestic architecture which I have discussed in Volume 1, one could say that the prefabricated economical house exhibits the lack of *interiority* in its outmost extreme. Consequently it likewise articulates the complexity of conditions causing this lack of *interiority* and the challenges affiliated with the picturing of a revelation of the architectural potential of the prefabricated house. As an example Arne Jacobsen designed a prefabricated housing system in 1970 of which one prototype was made which is today exhibited at the museum Trapholt in Kolding, Denmark. The house consists of plain cubic elements which are combined into a house. However, in experiencing the house today, it is Jacobsen's world renowned (and expensive!) furniture which signifies the quality of this house rather than the rational 'Kubeflex' project itself, furniture which the ordinary citizen intended as the costumer of the house would never be able to afford to equip the house with, see page 9. Hence, the choice to focus here on an actual relation between the spatial envelope and furniture, as unfolded in the theory development in Volume 1, is a deliberate choice: In pursuing an understanding of domestic architectural quality stemming from the ability of the spatial envelope to address the scale of furniture the question becomes architectural, a spatial economical and constructive architectural responsibility of the prefabricated house itself.

Summing up this introduction to the case study it is consequently my observation that the challenges of the prefabricated house are both spatial and technical. In referring back to Volume 1, it is my observation that the general challenges posed by the prefabricated house as a field bring my general critique of our decreasing involvement as architects with the spatial articulation and detailing of the general domestic architectural practice to a head. If drawing an immediate parallel between the primordial and, one could say, ideal conditions of architecture as being the result of the work of the tekton, as accounted for by Kenneth Frampton, with the conditions of the prefabricated house it becomes clear that what we are dealing with here is not just an increasingly complex context of multiple project parties (Frampton 1995). Rather, what we are faced with here is a context in which the house can be said to be 'context less' in more than one sense. Not only is the same house normally reproduced in different physical contexts, the house is also 'context less' in the sense that it is designed for an imagined and average inhabitant. In its extreme one could say that here the architect is evidently the only possible advocate of the inhabitant's needs, just as the house itself becomes dependent solely on its contents. When approaching the prefabricated house as a case for pursued application of the developed critical architectural theory of *interiority* developed in Volume 1, it is my observation that the discussion of

a spatial understanding of the home is likewise evidently a necessary point of departure here. The question of identifying the spatial principles from which the domestic architectural quality of a home emanates, which were the objective of the theoretical part of the thesis, is often completely overlooked within the realm of the prefabricated house. However, as discussed also in Volume 1, the picturing and revelation of the modern fabricated economical dwelling in general and the prefabricated house in particular is still an architectural challenge. It represents a context which cannot be neglected it is my claim. There is still a need to develop generally applicable solutions to the housing problems of our cities. In utilizing the prefabricated house as a particular case study, it is the specific conditions of this context which my research addresses and in which I am consequently pursuing a test bed for the interior architectural theory developed in Volume 1 of the thesis. In continuation hereof the particular research question guiding this case study is as follows: Can the developed interior architectural theory of domestic architecture be activated and utilized as a critical means for transforming the technical and economical elements of construction into experiences of *interiority* within the particular practical context of the prefabricated house?

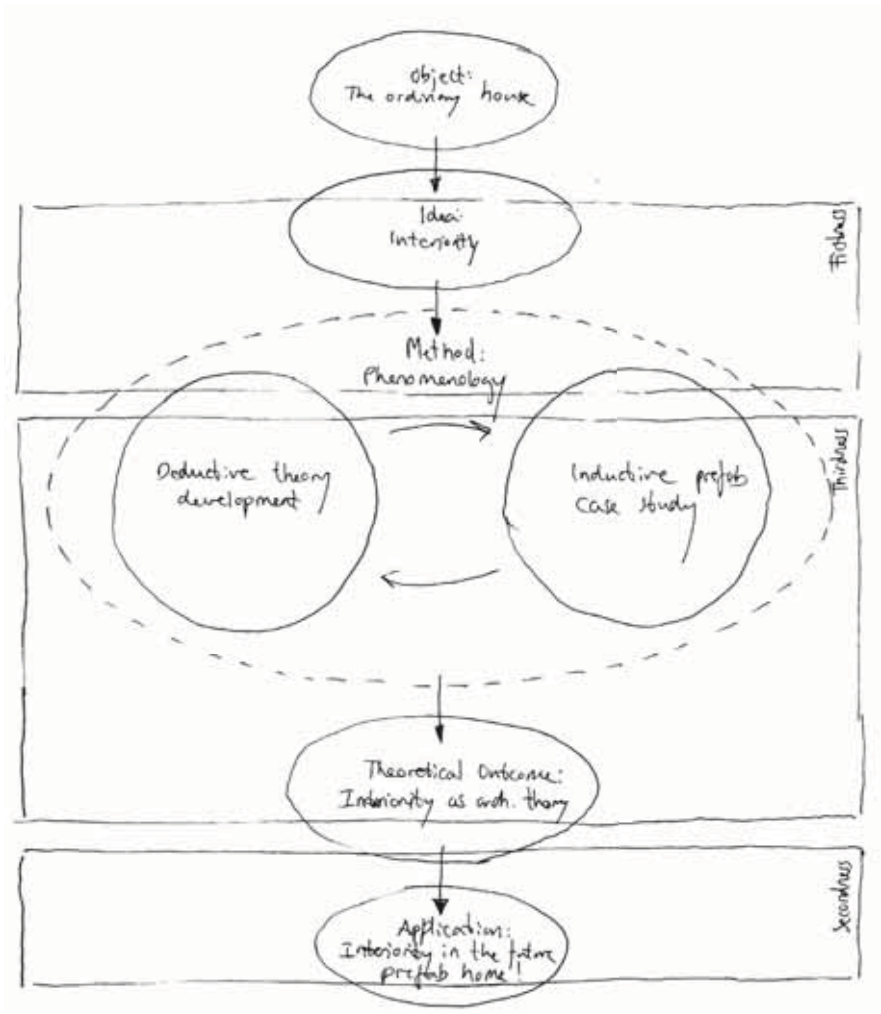
However, before continuing into an exploration of the particularities of this context I will briefly discuss how I have methodologically approached this proposed case study.

Chapter 2

METHODOLOGY

IN THE THEORY DEVELOPMENT motivated by the idea of *interiority,* I deliberately allowed myself to challenge the norm and to formulate a critique of the state of domestic architecture and to question the role of the architect in this matter. In taking the innermost architectural values of the home as my starting point one could say that I have begun my research in one extreme; in a sensuous and intimate understanding of architecture, concerned with sensuous detailing and materiality, which the necessary technical rationality and system represented in the prefabricated house defines an immediate counter position to. This comparison of seemingly oppositional realms of architecture; the conditions of the rational modern dwelling in our now global society set against a classical even primordial interpretation of architecture conceived as an intimate furnishing of places in which to sit, eat, sleep, bathe etc., facilitated by means of furnishing 'gestures' interrelating envelope and furniture, has allowed for an articulation of the cleft which is to be overcome if these are to be united. However, one thing is to theoretically discuss the nature of this cleft and the means for overcoming it, another one is to actually practically explore it, and to pursue an application of this critical architectural theory of *interiority* within it. Whereas the result of this theory development is a specific approach to domestic architecture as argued in Chapter 6 of Volume 1; a call for an increased level of spatial detailing by means of an actual spatial furnishing exploitation of the technical and economical elements of construction, this approach is now to be explored and faced with the realm of the prefabricated house through the proposed case study. As mentioned above, the object for this pursued application of the developed critical theory has been the cooperation with Boel Living A/S, and it has ultimately, and perhaps a bit too optimistically, been to pursue an actual improvement of the domestic architectural quality of the prefabricated house in practice as the ultimate aim for the thesis as a whole. Whereas a purely theoretical study possesses the luxurious right to unrestrictedly challenge boundaries, the real challenge, for me as an architect and for architectural research in general, it is my claim, lies in our ability to confront the realm of practice with these theories. In this particular case study about Boel Living, their production facilities, user group, working constellations and transportation and assembly methods has formed this realm and consequently a set of preconditions for the case study. An analysis of these conditions thus forms a necessary element herein which I will return to later. At a general level I have consequently pictured the case study as a study through which I would actually participate in and pursue an involvement with the product development process going on at the factory and one could claim that such a study is not without complications in a research context as it implies a personal involvement. If drawing a parallel to the sciences, it represents an experimental setup which cannot necessarily be reproduced by another researcher with the same result as one would necessitate within the sciences. If immediately describing my intentions for the case study, I would say that I have been picturing a utilization of the developed architectural theory of *interiority* as a lens through which to consider, or more precisely; critically re-consider and pursue development of the context of the prefabricated house as it is at Boel Living. A discussion of how to methodologically position and systematically structure such a study within a research context, how to include and evaluate observations, experiments and initiatives as a significant part of this study, is hence necessary before progressing.

In the chapter concerned with research methodology in the theoretical part of the thesis in Volume 1, I discussed the methodological implications of architectural research in general, how it can even be discussed whether it is actually possible to conduct research into an artistic field such as architecture. It has in this relation been my intention to pursue a general research methodology which would allow the research to take its starting point in the peculiarities of architecture; that which allows it to touch our emotions, 'move' us, as described by Corbusier (Corbusier 2000; 1923 p.4). Hence, rather than either adopting the research methodologies of other fields such as anthropology, history, or sociology as it is sometimes seen in architectural research or completely neglecting the established principles of scientific research in developing it as it can be seen when architectural research take the form of artistic development, as discussed by Linn Mo, it has herein been my intention to try to position the field of architecture in relation to these scientific principles (Mo 2003). In this matter my acquaintance with the work of Charles Sanders Peirce led to the inscription of architectural research within his general picturing of the research process as a 'Circle of inquiry' moving from the abduction of a research idea, a hypothesis, via the deduction of a general theory and into an inductive test/application of that theory as a accounted for in the first theoretical part of the thesis (Peirce 1998; 1879–1884 p. 288). Whereas the theory development itself has been pursued directed towards practice it can be said to be mainly positioned within the deductive part of the circle and was concluded with a discussion of how to approach application of the developed theory in Chapter 6 of Volume 1. In continuation hereof this second volume of the thesis unfolds an actual case study, positioned within the inductive part of Peirce's circle, see the sketch on page 13. It should in this relation be mentioned that whereas a presentation of the study and its results to some extent necessitates a linear account, the actual work has rather taken the form of a series of loops in which I have been moving back and forth between theory development and the pursued practical test/application in the cooperation with Boel Living which has eventually ended up pictured in Volume 1 and 2 respectively. These loops have naturally also given rise to reflections which have been fed back into the research idea concerning *interiority* itself. Consequently, I have pursued a way of structuring the case study through which to enable an inclusion of these reflections. Thus, just as the theoretical study of *interiority* necessitated the development of a structuring principle through which to progress from the general methodological framework of the circle of inquiry and into the



Sketch of the general methodological built up of the thesis inspired by (Brodersen 2007).

development of a particular research strategy, the pursued test/application of this theory here likewise calls for the development of a particular research strategy for unfolding this study. As mentioned above, the proposed test/application necessitates an actual involvement with the daily life at the factory including observations, participation and experiments, but also studies into its historical development and into the current research constituting the general field of prefabricated housing. Such a study cannot be done through the application of a singular tactic such as for example interviews or other surveys since what I am interested in is to explore and exploit the role of architecture and the architect herein. Consequently, I have chosen to define the study as a case study because it compares a series of study areas and also tactics within a real life context, the question, however, is how to structure the different parts which come together in the proposed study?

2.1 An architectural case study

As described introductorily by Robert K. Yin in his 'Case Study Research' the case study as such is inherently at the risk of being accused of 'downgrading its academic discipline' (Yin 2003b p. xiii). In positioning itself within a real life context and the researcher as an observer or even participant herein, the notion of a case study inevitably requires that the researcher leaves the controllable environment of the science lab. If drawing a parallel to architecture, one could say that such a study is at the risk of becoming a practice in itself rather than a research into the practice of the field. Yin's account for case study research takes its point of departure in the observation that case study research is a common term which however covers a variety of research designs. In continuation hereof Yin defines the term generally as an empirical inquiry that *"investigates a contemporary phenomenon within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident"* (Yin 2003b p. 13). Thus it is a major concern of Yin's that the notion of a case study should not be misconceived simply as a data collection technique but rather *"allows investigators to retain the holistic and meaningful characteristics of real-life events - such as individual life cycles, organizational and managerial processes, neighborhood relations and the maturation of industries"* (Yin 2003b p. 2). Seen in relation to the particular study of the prefabricated house here, this expansion of the notion of data collection in a real life context include contextual conditions and relations offering a potential to consider the research phenomenon, in this case the prefabricated house, as such, rather than as a controllable experimental setup which it is clearly not. Yin's description of case study research likewise argues that a case study inquiry collects and compares multiple sources of evidence just as it benefits from *"the prior development of theoretical propositions to guide data collection and analysis"* which is the starting point for my study here. The intention is to pursue test/application of the developed critical theory of *interiority* (Yin 2003b p.14). However, Yin's general account for the buildup of case studies, is rooted in the social sciences and therefore does not offer immediate tools for how to actually structure the particular architectural case study here. In this relation Linda Groat og David Wang propose to translate Yin's general description of the case study as an empirical inquiry that investigates a contemporary phenomenon within its real-life context into 'an empirical inquiry that investigates a phenomenon or setting' in their discussion of architectural research methods (Groat, Wang 2002 p. 346).

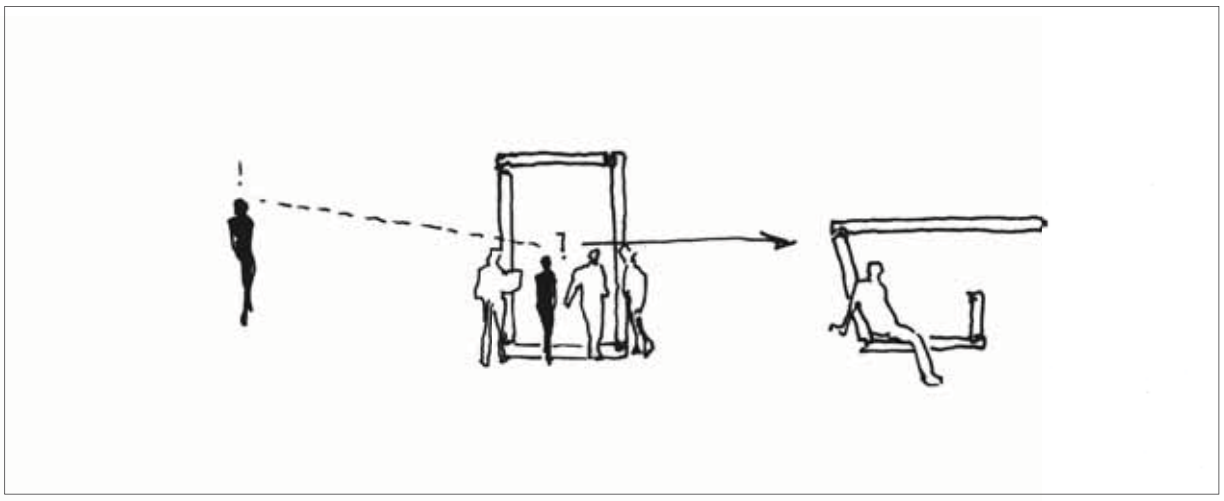
Referring to Jane Jacobs' urban studies of the 1960s through which Jacobs spurred a whole new way of utilizing personal observations of a particular context as research data; Groat and Wang position the architectural case study as an inclusive research method. In the case of Jacobs this approach allowed her to link a multitude of societal developments and trends in planning theory with actual observations, according to Groat and Wang exemplifying how the context of the case is virtually inseparable from the definition of the case itself (Groat, Wang 2002 p. 347). The case study thus compares a series of dynamic relations within a particular setting unfolding an inquiry which can according to Groat and Wang be exploratory, descriptive or explanatory but is always related to a general theoretical framework which it either seeks to develop or to test. Consequently, the examples which Groat and Wang present in their account for architectural case studies are mainly unfolded in observatory field studies in which the researcher, in line with Yin's general account, assumes a passive role in the setting. In the case of the prefabricated house here, the study is first and foremost intended as a setting for pursued test/application of the developed theory of *interiority* as stated. However, as implied in Peirce's 'Circle of Inquiry', it likewise feeds information back into the theory development motivated by a research approach which can be considered critical rather than exploratory, descriptive or explanatory it is my observation. As accounted for in the theory development in Volume 1, this choice of a critical general research design was motivated in the intention to activate and utilize my professional competence in architecture as the basis for the research. It has herein also been my observation that in order to do this, the practice of the field itself would have to become a part of the research. In relation to the case study unfolding a practical test/application of the developed interior architectural theory this critical point of departure simultaneously necessitates a personal entanglement with the setting beyond that of observation. As stated by Peirce; *"Deduction produces from the conclusion of Abduction predictions as to what would be found true in experience in case that conclusion were realized. Now comes the work of Induction, which is not to be done while lolling in an easy chair, since it consists in actually going to work and making the experiments, thence going on to settle a general conclusion as to how far the hypothesis hold good"* (Peirce 1998; 1879–1884. p. 288). If continuing this line of thought, the testing of the research question of whether the developed interior architectural theory of domestic architecture can be activated and utilized as a critical means for transforming the technical and

economical elements of construction into experiences of *interiority* within the particular practical context of the prefabricated house, is preconditioned by an actual active participation in this context it is my claim. Or to say it in another way; it would be impossible to conduct this study if not allowing myself to actually make architectural propositions herein, consequently, the research cannot be considered separate from my own personality and in continuation hereof it is a major issue in relation to the structuring of the case study to discuss how such pursued actions can qualify as part of the research.

Within the field of action research the act itself is the point of departure for research as a whole, a research tradition emanating in the work of Kurt Lewin from the 1940's. Peter Reason and Hilary Bradbury picture this rise of action research as an autonomous research strategy with the primary purpose of producing *"practical knowledge that is useful to people in the everyday conduct of their lives"* (Reason, Bradbury 2008 p. 3). Lewin's original model describing the process of action research takes its point of departure in an analysis of the context, which leads to the planning of an action, further onto the execution of this action and observation hereof before finally arriving at reflections which can be utilized in the planning of new actions (Dickens, Watkins 1999 p. 133). Here the research questions and plans for action are thus born directly within the context itself and focus is on how the researcher can take part in a team in a real life context. Thus, the issue of how to include action in research is intimately linked with the question of identifying the setup and parties involved within the particular context intended for the studies. In the proposed practical case study dealing with the prefabricated house, these parties are managers, workers, architects, engineers and of course the future inhabitant, even though the role and wishes of these are often not directly represented in the development process, as argued in the introduction. In action research the motive and background for the planning of actions hence evolves directly within this reality of the context and the team involved. It is herein a participatory worldview which motivates the notion of action research and through which it is intended to arrive at a *"'better' research because the practical and theoretical outcomes of the research process are grounded in the perspective and interests of those immediately concerned, and not filtered through an outside researcher's preconceptions and interests"* (Reason, Bradbury 2008 p. 5). When it comes to the proposed case study and the actions which I intend to become a part of described above, these actions however cannot be considered free of preconceptions. Rather, one could say that the concurrent theory development concerning *interiority* has equipped me with a set of presuppositions, a critical theoretical perspective through which to reconsider production and construction processes and hopefully test means for increasing the domestic architectural quality of the prefabricated house within its practical context. Even though both case study research and action research are strategies for conducting research within a practical context, the case study as a way of relating theoretical studies to observations of complex contextual linkages in practice and action research for pursuing a linkage of research and development directly within this context, both pursues a neutral positioning of the researcher herein. Thus, whereas the proposed case study can be said to fit within Yin's general framework for conducting case studies within a particular setting and it is here intended to incorporate actions in a series of loops as described within the theory on action research. Consequently, I have had difficulties in finding examples for how to deal with the fact that my engagement with the prefabricated house basically is critical, one might even say value-laden as discussed also in Volume 1. It is however my claim that this criticism is not tantamount to being subjective, as it is the result of a theoretical study which in the particular case of the prefabricated house here allows for an articulation of general architectural principles within a context which otherwise, as argued above, seems to turn in on itself and its economical and constructive boundaries. As argued above it seems to be a key issue in understanding the challenges of the prefabricated house, that at a general level the idea of a fabricated house has significantly detached home and construct in its original tectonic unity. Consequently it would be hard to imagine that a detailed focus on and discussion of the development of the necessary domestic architectural qualities of these houses would evolve from within this context itself, without being deliberately positioned there.

Consequently, it is my observation that it is a condition and a necessity of architectural research to acknowledge this need to activate our field specific theoretical knowledge, which is inherently value-laden as it must deal with the quality of our built environment as stated in Volume 1. Again this is not the same as to say that this knowledge is subjective, only that it cannot be measured and hereby studied solely through neutral observation, surveys or interviews. However, what it can be said to entail is an increased need to continuously reflect upon the development of the case study and to maintain honesty towards the observations and experiments done when theory meets practice in the case study as argued by Yin both in his description of the case study method and in his account for its applications (Yin 2003b, Yin 2003a). Consequently, I have tried to put focus on this reflective element, which is also a key issue in action research, when structuring the case study and presenting it here in the following. Thus it might be possible to use Yin's account for case study research as the point of departure for this structuring after all, if inscribing these peculiarities of the architectural field into his model. In the following I have consequently utilized Yin's description of the components of case study design to specifically structure the proposed study below.

Yin describes the components of such a research design as those of identifying *"a study's propositions, if any, its unit(s) of analysis, the logic of linking the data to the propositions and the criteria for interpreting the findings"* (Yin 2003b p. 21). As it is evident from the formulation of the research question for the case study, it is a proposition of the study here that the developed critical



Sketch exemplifying my intention to actively participate in the daily life at Boel Living during the architectural case study.

architectural theory of *interiority* can be utilized in improving the domestic architectural quality of the prefabricated house, that is ultimately what the case study proposes and investigates. In continuation hereof, the definition of the units of analysis, by Yin described as that of actually defining the 'case', immediately seem wider and more vaguely defined than in the examples which Yin present. In one instance Yin describes a case about the Korean firm Samsung which is a case study of the critical policies that make the firm competitive (Yin 2003b p. 25). Here understanding the Korean economic development is part of the context, and the case study also contains an embedded unit, Yin calls it; Samsung's development of the microwave oven as an illustrative product. Thus in describing the particular architectural case study here, the case is about Boel Living A/S, but the case itself is the prefabricated house as an architectural product. Therefore an understanding of the historical development of prefabrication in general as well as current research within this field is a part of the context of the study. Thus in general the case study can be described as consisting of two complementary parts motivated within the general theory development dealing with domestic architectural quality in general and the idea of *interiority* as a signifier hereof: These parts are a critical review of the historical development of- and current research related to the prefabricated house in general and an actual field study through which I have participated actively in the actual development at Boel Living. In continuation hereof I have chosen to utilize this division of the study as the means also for structuring this volume which presents and discusses the results of the case study as exemplified on page 13.

In continuation hereof the following Chapter 3 presents the first part of the case study, namely the research which I have done into the general development of the prefabricated house and the current research constituting this field, which can be said to form a general context for the case study from which to progress into the particular case of Boel Living A/S. Chapter 4 consequently presents and discusses the actual field studies and research actions which have been carried out at Boel Living as well as the findings of the case study represented in the selected papers. Hence it is also in chapter 4 that I pursue a linkage of 'data to the propositions' of the study if using Yin's terminology. At a general level the logic of linking data to propositions and the criteria for interpreting the results is inscribed in the general research methodology constituted by Peirce's circle of inquiry, thus in linking the observations and reflections resulting from the fields studies back to the theoretical framework. Specifically the research question for the case study whether the developed interior architectural theory of domestic architecture be activated and utilized as a critical means for transforming the technical and economical elements of construction into experiences of *interiority* within the particular practical context of the prefabricated house. The data of the study can hereby be said to be the houses produced at Boel Living as well as the processes from which they result. At the root of the field study hence lies a study of the company, its goal sets and processes as well as their products, which form the specific framework for participation and proposed actions and experiments.

In total this volume can be considered a case study report which presents and discusses the results of the case study as exemplified in the selection of papers included. However, as the PhD research has progressed, I have also had to face the fact that what can be done in the run of a PhD is limited just as the ways of reality are unpredictable and can (as it also should) affect research ideas and intentions. In Chapter 6 of the theoretical part of the thesis, I discussed the matter of approaching the application of architectural theory, constituting a pursued summary and practical positioning of the theory developed. It is clear that the application of architectural theory can never become explicit and predictable because of its inherent contextuality and dependence on the individual talent of the single architect to insist upon and to articulate the need and means for improving the quality of the built environment within the practical context. It is my observation that endeavoring a visualization and discussion of what this task involves and how to define the role of the architect herein is consequently a key issue not solely of architectural research itself but for the field as such. This observation has motivated the choice to present the field studies in a chronological manner as this allows me to focus on and discuss precisely this matter.

Chapter 3

THE PREFABRICATED HOUSE

WHEREAS THE THEORY DEVELOPMENT, presented in the first volume of the thesis, deals with the subject of domestic architectural quality in general and at a theoretical level, the case study here is as mentioned intended as a particular context for test and application of the developed theory of *interiority*. Such test and pursued application is however preconditioned by an introduction to the particularities of this context, its history and its future challenges. The study herein unfolds a need to zoom in on the prefabricated house in order to position these general theoretical conceptions concerning *interiority*, and the stated lack hereof, within this particular context. Consequently, this chapter is intended to introduce the context of the prefabricated house, its historical development and current definition as a research field forming a general framework for the particular case study about Boel Living which has its immediate emanation in the Danish housing market. Thus, the chapter will be built up accordingly starting with the general historical development of the prefabricated house from which to zoom further in on the current prefab research and finally on the particularities of the Danish context and the actual field studies done at Boel Living in Chapter 4. However before progressing it might be useful to initiate this review of the prefabricated house with an actual definition of the term itself.

In introducing the topic of their book 'Prefab' Bryan Burkhart and Allison Arieff define the prefabricated house in the following way; "*we admit to playing fast and loose with the concept of prefabrication here. Many of the houses presented in this book are not prefabricated in the strictest sense of the word. Not all were factory built and assembled. Some houses were built with prefabricated materials like aluminum siding. Some one-off homes were built as prototypes geared toward future mass production. In some cases, architects used prefabrication for custom homes. But all incorporate some element of prefabrication*" (Arieff, Burkhart 2003). Thus, in general, the boundary between traditional on site construction and prefabrication is fluent if what we are considering is its actual physical buildup. In Burkhart and Arieff's definition there are clearly a variety of user groups and economical conditions included of which the work of Mark and Peter Andersons presented in their 'Prefab Prototypes: Site-Specific Design for Offsite Construction' show examples in which prefab technologies are incorporated in highly specific one-of-a-kind homes (Anderson, Anderson 2007). However, whereas it is a definite and bright potential of prefabrication processes to allow for such overlapping or even a fusion of the unique which is achievable by few and the ordinary which is the reality for the many, a blind belief that this is about to happen any time soon and that the potential of mass customization processes will provide a quick answer hereto will be to cheat oneself. As stated also in Chapter 2 of Volume 1; on the one hand we have reached the conclusion that the modern vision of defining a reproducible solution to our domestic and urban architectural challenges has failed, however, on the other hand a discussion of what the necessary architectural contents of such a solution should be, still seems to lie at the core of the challenges which the general domestic architectural practice is facing today. Burkhart and Arieff describe how "*too often aesthetics, comfort, and quality have been sacrificed for the sake of the bottom line*" within the field of prefabrication which is unarguably true (Arieff, Burkhart 2003 p. 9). However, this bottom line is inevitably an inherent condition of domestic architecture in general, and of the ordinary prefabricated house in particular, and it is consequently my observation that the value of the prefabricated house as a case study lies in the particular relation which it unfolds between, the unique and the ordinary, the home and its necessary structural and constructive logic, however inevitably outplayed within the condition of the bottom line. In line with Colin Davies who introduces his book entitled 'The Prefabricated Home' by stating that it is his idea that "*a study of the prefabricated house might shed light on the true nature of modern architecture*" it is my intention here to utilize the prefabricated house as a means in addressing this bottom line, which simultaneously seems to define the boundary between architecture and plain construction (Davies 2005 p. 7). Thus, rather than introductorily defining the prefabricated house solely by means of its physical characteristic in being 'prefabricated' to a certain degree, it is its potential capacity as a liaison between the necessary domestic architectural quality of the home as a sensuous individual but also societal concern, and the economical and constructive market conditions of its practice which define its meaning in this volume. It is my intention to pursue a continuous relation between the conditions of the before mentioned bottom line and the developed critical architectural theory of *interiority* developed in the first volume of this PhD thesis. Consequently, it is also a mapping of the general challenges defining the revelation of this potential liaison between the necessary domestic architectural quality of the home and the bottom line of the structural and economic system underlying prefabrication which is the objective of the following review of the history of the prefabricated house.

3.1 A brief history of the prefabricated house

In the introduction I touched upon the fact that the historical emanation of the prefabricated house is not explicit. Rather, the development of prefab technologies has evolved gradually from the utilization of Pattern Books in Great Britain, from where panelized houses were shipped to Cape Ann as early as 1624, to the Swedish wooden log cabins and onto the development of kit houses which were shipped by rail during the Californian gold rush (Arieff, Burkhart 2003 p. 13). However, in continuation of the delineation made to the problem area of the modern dwelling in the theoretical part of the thesis it is the objective here to study domestic architecture, here prefabrication, from the point at which it became an architectural and societal concern. Again the development is fluent, but architects began to gain significant interest in the utilization of prefab technologies coming from the automotive, nautical and aeronautical industries at the dawn of the 20th century. Here, it was as mentioned, the image of Ford's assembly line production of cars, which

Complete volume-element being craned in place on site, Boel Living, fall 2007 .

spurred the architectural and societal vision that the application of similar principles in the production of houses offered the means for improving the quality and economy of domestic architecture; a potential distribution and democratization of architecture for the ordinary family as envisioned in the writings of for example Corbusier (Corbusier 2000; 1923). Hence it is here that my history of the prefabricated house takes its starting point. However, whereas the design and construct of the car and the airplane are tectonically born, one could almost say, inside the factory where designers, managers and workers are inherently and necessarily working on the development of their projects in a joint venture, the fusion of industry and architecture on the other hand seems to have unfolded a series of paradoxes. Whereas the example was the smooth and dynamic form and construct of the car, the design of which sprang from the novel steel fabrication processes, the house, which has its historical emanation in the craft of construct, had to be adapted to these processes.

When the industrial development gained significant speed around 1900, this development was hence also expressed in an encounter between the architects' vision and an industry of prefab construction which had existed since the colonization seemingly without the involvement of architects and their societal and architectural visions. As accounted for above this industry did produce prefabricated buildings and also dwellings, but was mostly driven by the need for soldier and hospital huts and other more or less temporary structures related to modern warfare and colonization as described by Herbert, Davies and Vogler (Davies 2005, Vogler 2005, Herbert 1984). These were relatively primitive in the sense that they consisted in traditional wooden construction but were highly prefabricated in the sense that they shipped as complete flat-packed kits which could be quickly erected. Hence, it was an industry which was actually quite widespread and effective but which made use of rather traditional construction technologies that met the Modern architects as they gained interest in the industry and began to 'dream of the factory-made house' as Herbert puts it, a dream which included big assembly lines and a highly effective production utilizing novel building materials such as reinforced concrete and steel (Herbert 1984). Thus, already in the emanation of this dream of the prefabricated house, there seems to have been a cleft between the architectural vision and an industry which was already there and which in principle functioned well without the involvement of architects. The vision of the prefabricated house inevitably represents and articulates the meeting between architecture as a functional but also aesthetic art form which holds the potential to 'move' its inhabitants as stated by Corbusier, and ordinary construction which functions at best, but only in few cases enriches our lives emotionally. The prefabricated construction industry, thus, already existed when it became also a societal and architectural concern and focus, consisting of processes which may have been rationalized into inventions such as the 'Balloon Frame' of 1833 which was applied extensively in the rapid birth of American cities such as Chicago, but still consisted of logs and nails which had to be joined more or less manually. As it has been done by Vogler, the meeting between the two can be characterized as a meeting between intellectual postulation and industrial reality (Vogler 2005 p. 12). With the development of the Modern movement an encounter between architects and the ordinary construction industry, in which they had not before been a part, was facilitated. Referring to the observations made in Volume 1, it seems an inevitable fact that this apparently irreconcilable encounter is still evident today, within the general realm as a whole, as well as within the realm of the prefabricated house.

Gropius' early call for an industrialization of houses, which occurred already in 1910, can be seen as the starting signal of this encounter. At the time of the founding of Deutscher Werkbund in 1907 by 12 artists and 12 manufacturers intending to fuse art and industry, Gropius had acquired a position as an assistant at Peter Behrens' office. As chief assistant in 1910, Gropius composed a memorandum on the industrial production of buildings addressed at the president of AEG for whom Behrens was doing a complete 'industry architecture', one could almost say; including logo, products, and factory buildings. Although probably written under the influence and supervision of Behrens, Gropius pictures his memorandum as a seminal paper which would come to spur his career as stated by Herbert (Herbert 1984 p.33). In this 'Programm zur Gründung einer allgemeiner Hasbaugesellschaft auf künsterlich einheitlicher Grundlage' Gropius argued for the development of a general housing construction company by utilizing artistically standard principles to generate a unity of art and technique. Architecturally his proposal was based on the manufacture of a large variety of prefabricated standard dimensioned elements ranging from staircases to windows and doors ready for assembly according to the variability of individual needs. Hereby Gropius spurred the focus on the need for flexibility which came to characterize the vision as well as the actual development of the prefabricated house in general as argued introductorily above. In this relation Gropius' early thoughts, as represented in the memorandum, can be said to take this idea of flexibility as its point of departure. Also in 1910 Le Corbusier, at that time Charles Edouard Jeanneret, likewise turned to Behrens, whose office he considered the place to be in order to pursue his newly acquired interest in the future potentials of architecture in the encounter with industry. However, before progressing into a discussion of the actual practical prefab projects resulting from these initiatives, which were initially hindered by the break out of the war in 1914, I would like to elaborate a little bit upon this aspect of flexibility and system development versus the form and quality of the eventual home and the two young men who came to Behrens' office; Gropius and Jeanneret: Whereas Gropius seemed to embrace the thought of an architectural system, and the development of uniform artistic principles, Jeanneret's first encounter with this realm also rose questions causing him to reflect upon the nature of

the architect's task expressing a nascent conflict in the idea of the house as a product. In a letter to his older friend and confidential the music critic William Ritter, Jeanneret actually expressed dissatisfaction with the work at Behrens' office: *"The work I'm required to perform leaves me indifferent. I now judge quite severely a man who has allowed himself to be surrounded by the fatal cortege of fame; though a powerful personality, Behrens has become a victim of his successes. Eager to make money, he undertakes too many projects"* (Weber 2008 p. 77). It was Corbusier's observation that Behrens had lost track of what the office produced and that the work was becoming a routine consequently lacking emotional character. This observation caused Jeanneret to conclude the letter to Ritter by stating that; *"An architect, as I envisage him, must be above all a thinker. His art, consisting of abstract relationships which he cannot describe or depict except symbolically – his art does not require a cunning hand. Indeed such a hand could be fatal. But this manipulator of rhythms must posses a fully developed brain of extreme flexibility"* (Weber 2008 p. 77). Both young men, thus, spoke and thought of a necessary flexibility in their early encounter with the industry; Gropius of a flexibility of the house as a product and Jeanneret of a necessary flexibility of the mind of the architect, an observation which I will return to later. However first I will continue the historical account for the development of the prefabricated house as it came into being spurred by these early statements. In this matter I will compare the development of the careers of the two young architects Gropius and Jeanneret's, as I find that such comparison may help map out the future potential of prefabrication but also the persistent challenges with which it still struggles.

As mentioned, the actual practical experiments with the prefabricated house were initially hindered by the break out of the First World War, but in the early 1920's the development regained momentum. Here the manufacturer M. Früges offered Jeanneret, who had now changed his name into 'Le Corbusier', the opportunity to pursue the realization of his 'Dom-ino' house prototype of 1914, just as Gropius pursued his goals through his role in the establishment of the Bauhaus where he, together with Adolf Meyer proposed the development of a system of 'Baukasten' (building blocks) which the architect would assist the clients in combining as described above. Whereas Corbusier's 'Pessac' houses got built hard criticism from other architects hindered them from being sold and they ended up as a witness that also politics plays a major role in architecture particularly within fabrication. Gropius' 'Baukasten' remained prototypes and he instead threw himself into the work at the Bauhaus where his design of the Bauhaus buildings at Weimar became one of his major works before the break out of the Second World War caused him to flee Europe. Also Corbusier's grand visions of applying his ideas of the mass produced machine for living at a grand urban scale found its physical display in single projects, mostly villas, rather than actual industrial achievements. As stated in the first volume of the thesis, it became the functional and emotional needs of the architecture of the home itself which manifested his main interest despite his persistent and loud call for the development of a 'machine for living'. The actual technical and economical conditions of prefabrication he on the other hand gladly overlooked in order to achieve these necessary architectural qualities as he often winded up executing his designs in brick rather than the concrete elements which his 'Dom-ino' house depicted as accounted for by Frampton and discussed in the analysis of his 'Villa Stein' in Chapter 5 of Volume 1 (Frampton 2001).

On his emigration to America in 1937 Gropius became Professor at Harvard but was still determined to pursue his vision of prefabrication. Together with the younger architect Konrad Wachsmann, who also fled Europe, Gropius envisioned the American market and the establishment of the 'General Panel Corporation' in New York in 1942 as the ultimate opportunity to realize the dream. Wachsmann, who was trained as a cabinet maker before becoming an architect and who had worked as chief designer at the German housing factory 'Christoph and Unmack', was one of the first architects to actually engage in such cooperation between industry and architect as accounted for by Herbert (Herbert 1984). His training as a cabinet maker seems to have equipped him with a particular technical ability to penetrate the challenges of prefabrication, which as an effect of being prefabricated in modules of varying sizes requires a precision which is otherwise unseen in on-site construction work where adjustments are made as the work progresses. Therefore Wacksmann had already at his work for 'Christoph and Unmack' focused his attention on the solution of how to join the prefabricated elements in the development of a spatially flexible system and had begun to experiment with the development of a panelized system, manifest in a universal jointing mechanism. Gropius, who had met the younger Wachsmann earlier used his connections to help Wachsmann get released from France, where he was being held interned as an alien enemy, and invited him to come to America where they started working on what would eventually become known as the 'General Panel System' together (Herbert 1984). In their cooperation Gropius assumed the role of the facilitator and mentor and Wachsmann was in charge of the actual drawing work. The 'General Panel System' was based on Wachsmann's previous work and also on Gropius' early call for a flexible building system adaptable to the individual needs of the future users. Again Wachsmann's point of departure was the solution of a jointing mechanism, actually a great part of Herbert's account for Gropius and Wachsmann's 'Dream of the Factory-Made house' portrays his stubborn and intense work on developing this universal joint (Herbert 1984 p. 243-299). Consequently, the 'General Panel System' came out with no proposed ideal plan solutions, Wachsmann had deliberately chosen not to draw any definitive housing models (Bergdoll, Christensen 2008 p. 80). Instead the drawings which Wachsmann had spent years refining contained only the construction system itself; consisting of 10 types of 40by120-inch panels and

the jointing mechanism ready for production. However, as Herbert's detailed review of the progress of the work of Gropius and Wachsmann describe in its utmost detail, the revelation of their dream of the factory made house was not just a long time coming, it actually ended up bursting in 1952, when the 'General Panel Corporation' finally went bankrupt after 10 years of lacking funds, market changes and even tolerance problems. According to Vogler it was an effect of miss-management, lacking funds, and missed time-to-market, just as Herbert's conclusion seems to be, that the ultimate failure of the project can be ascribed to these factors which can be said to be outside the product itself (Vogler 2005 p. 17). It is my observation, however, that the paradox of the failed dream is also to be found in the product itself, or in the missing product one could say: Gropius and Wachsmann actually ended up designing a construction system rather than a home. In their strive for flexibility, it is my observation and claim that they stopped thinking as architects and began to works as engineers as exemplified in Wachsmann's endless search for the perfect joint which seemingly kept him from actually envisioning the architecture of the home itself. The resulting system, like so many other prefab systems before and after, completely lacked the spatial detailing allowing it to eventually function as a home, not to mention to 'move' us emotionally as envisioned by Le Corbusier. Instead of evolving the house and its construction from its necessary *interiority*, as argued in the theory development, its domestic architectural became assigned to the economy of construction, if not plain forgotten.

If returning to the comparison of the careers and initial prefab visions of Corbusier versus those of Gropius and also Wachsmann, it is my observation, that whereas their initial interest in fabrication as an architectural vehicle was common, their subsequent engagement with the topic went separate ways. Corbusier's actual engagement with the practice of prefabrication turned out to be sparse despite his loud proclamations. And even though he initially did share Gropius' vision of the ultimate need for flexibility and individual adaptation, the quality which came to signify his built works, is the result of a unique spatial development and approaching of the spatial envelope to the sensuous scale of furniture as stated in the theoretical volume of the thesis, rather than an adaptation to the necessary economy of prefab construction (Frampton 2001). Even when finally realizing his Unité block in Marseille, the closest he ever got to realize his urban visions of improving the modern dwelling conditions, it is the specificity of the detailing which makes the house work and which has made it appreciated. This block is clearly the result of a detailed work of an architect and it is far removed from the initial depiction of the domino skeleton which was to be fitted individually in plan according to the needs of the individual through the introduction of his standard furniture units as accounted for in his 'Precisions' (Corbusier 1991; 1931). Corbusier's works never became prefabricated; they were, except for a few prototypes, unique works which are studied today because of their unique domestic architectural qualities such as I have done in the theory development. Gropius and especially Wachsmann on the other hand really got their hands down into the industry of prefabrication. They learned that in order for us as architects to at all make ourselves heard in this context, it is a necessity to pursue an understanding of the underlying economical, constructive and production technical conditions hereof. For Wachsmann especially, his actual engagement with Christoph & Unmach seemingly led him to pursue an embracing of the challenges of prefabrication as a whole beginning with the constructive and production technical challenges of the actual jointing of the prefabricated elements. Paradoxically this endeavor, which was undoubtedly necessary in order to foster a fruitful cooperation between the architect and the ordinary construction industry where architects then and still even today do not play a significant role in the development of the building system which eventually makes up our houses, however ended up resulting in even fewer practical results. Gropius and Wachsmann's panelized proposal for a prefabricated housing system ready for mass production may have included an architectural refinement in the solution of the jointing of the panels but as concluded also by Harry Bergdoll it did represent a significant development in comparison to for example the more simple Balloon Frame system (Bergdoll, Christensen 2008 p. 80). As it came out in the last phases of the long struggle, when the system was finally to take the leap from the drawing board to actual production, even these technically refined joints turned out to be problematic as they did not allow for sufficient tolerances as they were refined to the level of cabinetry rather than building construction. In addition I find it worth stressing the fact that the products of the 'General Panel System', were eventually not houses, but as the name implies a series of parts, thus neither at the architectural level did the system represent a significant development. It is consequently my claim that in the endeavor to understand and solve all the constructive challenge related to the prefabricated house, Gropius and Wachsmann actually forgot their origin in architecture; rather they ended up attaining the role of system engineers.

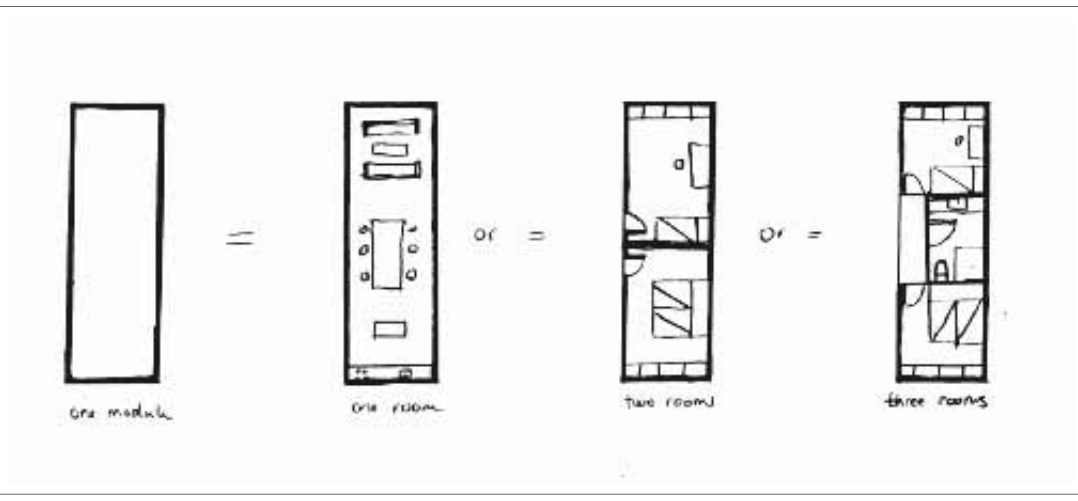
The two parallel stories of Gropius and Corbusier, it is my observation, depicts a central paradox in the history of the prefabricated house, namely the fact that attempts which have been made by architects (and by industries) to penetrate this challenge of uniting home and system has seemingly either resulted in: A singular spatially interesting prototype or a headlong dive into the constructive and technical premises of prefabrication which eventually falls silent when considering its domestic architectural qualities. Consequently the history of the prefabricated house is often, and with reason, presented as a dual history in which companies like 'Christoph and Unmack' in Germany or 'Sears, Roebuck & Co.' in America on the one hand produced and kept on mass producing houses throughout the development of the Modern movement. The most characteristic and somewhat frightening examples hereof are to be found in the endless trailer parks in the US and in developments such as those

of the developer William Levitt endless reproductions into 'Levittowns', not to mention how prefab technologies have been used in high rise developments experienced literally as what they are; concrete blocks of which the now demolished 'Pruit Igoe' development is as accounted for by Charles Jencks an example (Jencks 2002; 1977). On the other hand, the involvement of architects has resulted in very few actual physical built works and have in most cases remained prototypes of which Corbusier's 'Dom-ino' of 1914, Gropius' 'Baukasten' of 1922, Buckminster Fuller's 'Dymaxion' house of 1927 and 'Wichita' of 1944, the case study houses initiated by the Editor of the 'Arts and Architecture' magazine John Entenza and designed by architects such as Ray and Charles Eames, Richard Neutra and Craig Ellwood in a period from 1945 until 1962, Jean Prouve's 'Maison Tropicale' of 1949, Archigram's 'Living pod' of 1965, Arne Jacobsen's 'Kubeflex', of 1971, Jørn Utzon's 'Espansiva' of 1969, Matti Suuronen's 'Futuro House' of 1968, Richard Rogers 'Zip-Up' enclosures of 1986, Richard Horden's 'Yacht house' of 1983, Greg Lynn's 'Embryological House' of 1999 and Luigi Colani's 'Rotorhaus' of 2004. Together the architectural prototypes and the ordinary housing industry form but also articulate the split which still exists today in domestic architecture between the ordinary construction for the many and the custom designed architect drawn home which is a privilege of the few. What it also shows is that there is still a need to pursue a more fruitful relation between architecture and industry, and that the key to such development inevitably lies in the relation between home and system; that is in how the necessary architectural qualities defining the home, the necessary *interiority* as argued in Volume 1, can be integrated directly in the production system and hereby in the technical and economical constructive elements themselves. Thus, at a general level, this split seems to be rooted in the paradox unfolded above, hence in how we have as architects envisioned the prefabricated house not to mention how we have pursued action in the involvement with the industry. It can hereby be referred all the way back to the reflections which the work at Behrens' office provoked in Corbusier's mind; namely to the discussion of the architects' role and responsibility herein. However, in pursuing an understanding of what this means within the particular context of the prefabricated house, a more elaborate view of what it actually entails to begin considering the house as a fabricated product versus as a traditional and unique onsite work is needed.

3.2 'House production'

Whereas the boundary between prefabrication and traditional on-site construction is as mentioned fluent, prefabrication at a general level entails that instead of being erected bit by bit on site, it is prefabricated in elements which are then transported to the site and assembled. Hence prefab construction can take many configurations or varying degrees of prefabrication, one could say; consisting of small elements such as beams, columns and window sections, larger complete planar wall, floor and ceiling elements or even complete room sized volume elements of which it only takes few to make an entire house. Either way it is my observation that it introduces a need to understand and to emphasize and understand the coordination, transportation, weight and assembly of parts in the construct of the house as evident in Wachsmann's detailed construction studies (Herbert 1984). As stated in the introduction it was the automotive, nautical and aeronautical industries which inspired the architectural and societal vision of the prefabricated house, hence also an encounter between the mobility related to these novel means of transportation and the home which (at least in the Western culture) is in its origin a contextual and fixed place. The parallel between the car as a mass product emanating from Ford's assembly line and the house has often been highlighted as a kind of reason for the idea of the prefabricated house, such as for example Corbusiers 'Citrohan houses' named after the Citroën cars witness (Corbusier 2000; 1923 p. 225-266). However, as the history of the prefabricated house has shown this parallel is perhaps not as immediate as first anticipated: First there is the issue of scale and purpose. Whereas the car runs of the assembly line complete in one piece ready to cruise the roads, a single family house generally needs to be transported in elements to be assembled on site, where it is to become a fixed part of a specific context. Secondly the car was as mentioned born in the factory and in the utilization of novel industrial processes such as steel and aluminum processing and as a product of limited durability whereas the house emanates in traditional materials and processes and is generally expected to last. Maybe consequently, attempts such as Fuller's 'Dymaxion House' or Matti Suuronen's 'Futuro House' to actually conceive a house as a complete factory made transportable product literally lending its form and construct from the car and the airplane have never reached mass production except for the American trailer homes which, however, have often been objects of critique rather than desire.

Up until now most of the prefabricated houses, which have actually reached production, have been made up of either a panelized solution where planar wall floor and roof elements are packed flat and erected on site, or as volume-element construction where complete room-sized elements are transported and craned in place (Arieff, Burkhart 2003). Gropius and Wachsmann's 'General Panel System' is an example of the first and Moshe Safdie's habitat '67 of the latter. Hennebique's prefabricated concrete signalmen huts seem to have been the first examples of complete fabricated volume-element constructions which were delivered by train and hoisted into place by crane already in 1896, panelized systems were developed even earlier (Vogler 2005 p. 11). Also, the houses which have reached production have, except for experiments in concrete, steel, aluminum, plastic and composites mostly been simple wooden constructions. Thus, rather than highly effective and automated factories, even today these factories are perhaps better described, as Vogler does it; as building sites under a roof (Vogler 2005 p.38). Except for the factories in Japan, which are relatively developed, the fabrication of houses



The prefabricated house has often ended up as a mere constructive framework rather than a sensuous and inviting home.

is still highly dependent on hammer and nail and there seem to be both economical and constructive reasons as to why this is (It should in this relation be mentioned that in Japan the prefabricated house has emerged as a solution for middle class to rather wealthy clients and thus have not been subject to the same societal and economical preconditions as those I am discussing here in relation to the modern dwelling. Actually hammer and nails have often proved more effective, as the prefabrication of tailored elements at the factory have caused tremendous tolerance and tightening problems in the assembly phase, just as the need to conceive of the house as a modular assembly have often caused an additional material consumption in for example horizontal divisions such as in Jørn Utzon'z 'Espansiva' system for example (Beim 2004 p. 119-133). Often the simple wooden construction has proven the cheapest and easiest to adapt. As an example wood frame construction was chosen exactly for this reason, when Boel Living A/S initiated their production in 2007. It seems that this inherent modular built up of the prefabricated house from a series of elements of various sizes and degree of prefabrication is at once the potential and a significant key to an understanding of the challenges which it is also subject to. Rather than admitting to this assembly process and exploiting its particular potential architecturally the prefabricated house has been and is still often endeavored disguised as a 'real house' by covering for example its modular joints with layers of paint and plaster instead of articulating them in a development of an autonomous architectural language of the prefabricated house (Vogler 2005). In summing up one could say, that the prefabrication of elements and especially the development of complete three-dimensional volume-elements, theoretically provides a number of advantages concerning production, assembly and herein a decrease of cold-bridges and work time at the building site not to mention a potential for integrating 'gestures' of *interiority* directly within the construct itself as discussed in Volume 1. However, as pictured in the historical development of the prefabricated house, and as it has appeared from the studies of Herbert, Davies and Vogler alike referred to above, there are also a number of complexities connected to the introduction of modular industrialized housing production and industrialized architecture in general (Davies 2005, Vogler 2005, Herbert 1984). Whereas in traditional production there is a rich possibility to adapt the solutions as construction develops and hereby to readjust tolerances etc. along the way, the industrialized house requires a completely different level of detailed planning and hereby a precise knowledge of the desired end product. Tolerances, assembly and detailing must run smoothly, and likewise the overall composition requires a faultless load transmission and tightness in each element as well as in the assembled house. The house must be considered within a system so to speak it is my observation. However, as demonstrated by Herbert and Davies, until now many examples have showed that the detailed planning and high precision demands required in the development of such industrial production systems has often caused the costs to exceed the costs of traditional production (Davies 2005, Herbert 1984). In considering the challenges of the domestic architectural quality of the modern dwelling in general, this leaves us literally at a status quo in developing the societal and architectural potential of the prefabricated house as a solution to these challenges.

Nevertheless the general belief in the prefabricated house is intact and even growing. The bookstores are loaded with titles such as 'Prefabulous: The House of Your Dreams Delivered Fresh from the Factory ' and 'Prefab Modern' etc. (Koones, Susanka 2007, Herbers 2004). Today, however, it is not the mass production of the industrial assembly line which keeps the dream of the prefabricated house alive. Rather, it is the promises of novel CAD/CAM rapid prototyping technologies as mentioned also in the introduction and as exemplified in for example (Pérez Arroyo, Atena & Kebel 2007). However, whereas these may allow for an exploitation of a new variety of form, a general implementation of these technologies is still, it is my observation, dependent on the development of a general understanding of how the development of the production system and actual jointing of constructive elements relate to the development of the necessary domestic architectural qualities of the house itself; its *interiority*. As documented in Vogler's market-analyses in which he compares the share of prefabricated houses in Europe, the US and Japan one can see that the success of the prefabricated house is still limited in terms of numbers (Vogler 2005). In this relation I would like to add that if we look at the societal and architectural premises of the original modern dream of the fabricated house it is my observation that the success is even smaller: In general the prefabricated house has not been cheap, fast and easy to produce, and in the few cases where it has been, its' domestic architectural qualities have been difficult to identify. In his review of the topic of the 'House as a product' Vogler ends up concluding that "*the real conflict is to be found within the construction industry, in the difference between the traditional builders and the prefab builders*" and that the prefabricated house has not yet found its identity as a product (Vogler 2005 p. 28). In the light of the above review of the history of the prefabricated house this conclusion is obvious to follow and an important call for critical studies into the subject which I share as a basis for further research. As argued in his extensive review of the history of 'The house as a product', analytical and historical literature looking into the lessons which can be learned from the successes and failures of prefabrication is scarce (Vogler 2005 p. 6). Since Gilbert Herbert's review of the works of Walter Gropius and Konrad Wachsmann of 1984, Colin Davies' 'The Prefabricated Home' of 2005 is the first work to critically assess this context historically, and in continuation hereof to discuss the future role of the architect in this industry as it is likewise my endeavor here. To use the words of Vogler, there is a need to critically engage with the question of the 'industrial architect'; our engagement with the construction and managerial processes which we otherwise often detach ourselves from (Vogler 2005 p. 6). It seems that in general, the gap between home and system and herein between architect and industry is still wide. In research there is a tremendous amount of work going into fields such as LEAN and Agile construction. However, as I have experienced and will get back to later, most of this research and the actual development of the construction systems eventually making up our houses, is taken on by engineers and managerial fields; the international as

well as the Danish Group for Lean Construction counts very few active architects (Lean Construction Institute 2011, Lean Construction - DK 2011). On the other hand architectural research as discussed in Volume 1, often tends to turn in on itself describing the aesthetic dimension of architecture without confronting it with its economical and practical realm. The establishment of the Center for Industrial Architecture 'CINARK' at The Royal Danish Academy led by Anne Beim is however one of a few significant examples witnessing that there are also architects and researchers trying to bridge the gap between architect and prefab construction industry. Since 2005 they have published research reports dealing with the topic of 'Industrialized Architecture' in general, just as they have tried to define 'Architectural Quality in Industrial Building Systems' and to map 'Quality Goals for the Architectural Design Process – focusing on Industrialized Construction', and for discussing 'User involvement' and 'Architecture and Mass Customization'. They have also done more specific reports on the architectural potential of specific building materials such as brick and concrete forming a solid base for further research into the gap between architecture and industry (Beim, Vibæk & Ryborg Jørgensen 2007, Vibæk Jensen, Beim 2006, Ryborg Jørgensen 2007, Manelius 2007). Also the research being done at the 'Lehrstuhl für Gebäudelehre und Produktentwicklung' at TU in Munich led by Richard Horden is an important reference to make in this relation. Since 1996 the Institute has been doing research into what they call 'Micro Architecture' actively exploiting the boundaries between architecture and product design in a practice oriented form of research which has included actual prototyping of several lightweight architectural products such as the 'Micro Compact Home', which was also exhibited at the 'Home Delivery' exhibition at MOMA in New York in 2008 (Horden, Blaser 1995, Horden 2008). This exhibition is another visible sign that the dream of the prefabricated house is still alive and even flourishing, particularly the book accompanying the exhibition spurs a discussion of how novel CAD/CAM and rapid prototyping technologies can be applied in a re-engagement with the prefabricated house, a publication which not only spins of the current 'fashion' one could almost say of the 'prefabulous' house, but also repositions the societal and architectural responsibility of the original Modern vision in presenting prefab technologies as a means for rebuilding catastrophe areas such New Orleans. The project exhibited concerning New Orleans facilitated by Lawrence Sass from the School of Architecture and Planning at the Massachusetts Institute of Technology is presented side by side with Jeremy Edminston and Douglas Gauthier's 'Burst*008' which is not so much about economy, but explores the potential of these same technologies as a means for creating a fully parameterized production system enabling mass customization and instant 'printing' of the bits for the house (Bergdoll, Christensen 2008). It is in this relation interesting to note how the resulting skeletal construction, although of a more organic form, shows significant resemblances with the simple wood frame construction systems in terms of assembly which is done by manpower.

Also the research being done at the TU in Delft, where the research group 'Concept House' initiated from the Chair of Product Development at the faculty of Architecture pursues a *"radical progress in the field of customized industrial housing where the emphasis lies on the 'individualization of industrialization"* focusing on the introduction of CAD/CAM technologies and the use of new materials and techniques, in the making of a highly consumer oriented environment (Eekhout 2005). This project group established in 2005 has held yearly symposia with published proceedings facilitating an elaborate discussion of the house envisioned as a technical product. As stated by Mick Eekhout in his introduction to the first one of these proceedings the group considers the development of the future dwelling and intends to *"form a dialogue between ambitions on the one hand and construction materials on the other hand, which will be selected and optimized according to their functions, abilities and properties. This is in high contrast to the traditional way of building present in the current building industry"* (Eekhout 2005 p. 3). Thus, in continuation of the work being done at CINARK but also at TU in Munich and as it is the approach of Vogler in his extensive report on the subject of the house as a product, there is a huge amount of research being done into the material and construction technical aspects of prefabrication as well as to the subject of user involvement and means for arriving at a mass customized reality of the future prefabricated house. This research witnesses that there is still a belief and a will among architects to try to understand and develop the potentials of the industry and also that there is still a widespread belief that the key to the development of the future dwelling springs from technology. This approach and will to engage with the industry is indeed needed. However, it is also my observation, that when considering this technical context, there is also and most importantly a need to reverse the question and to begin with the home, which the implementation of prefab technology should eventually amount to, so to speak: To ask what the spatial principles signifying the home are, and to let these precondition constructive and production technical ventures. In continuation of the above review of the history of the prefabricated house it is my claim that we often tend to assume a common understanding of what a home is, and that this assumption sometimes causes us as architects to loose attention to that, which is in principle our core competence, namely the spaces which eventually make up the functional and emotional experience of the home. The theory development presented in Volume 1 concerning *interiority* can be seen as an attempt to develop a theoretical understanding and articulation of these principles and which I have herein documented the need to pursue application of within the particular context of the prefabricated house.

In summing up the above review of the historical development of the prefabricated house and the current research defining it as a field, there is in general a number of boundary conditions which must be considered before construction of a prefabricated house can commence; preconditions which

I have only begun to grasp the significance of in the actual engagement with the production at Boel Living A/S and which I will get back to in the following chapter. These conditions have to do with the development of the right construction system and how this system relates to the desired form of the home itself. Going through the literature and examples of prefabricated houses from different eras this interrelation of system and home has appeared to be a key issue when evaluating the success of the different initiatives. When looking at the history of industrial architecture many architects, for example Konrad Wachsmann as demonstrated by Herbert, have become fascinated with the idea of developing a flexible universal construction system, from which all desired houses imagined by the users could be developed (Herbert 1984). There seems to be an inherent contradiction in this interrelation of form and system; whereas a system is general, architectural form must have specific characteristics to be of a high quality. One could say that whereas an industrial system requires simplicity to be efficient, the house as architectural form requires a level of complexity to be an interesting experience. This contradiction of system and home is likewise apparent in both practice and research concerning the industrialized house. The complexity of form, the design process, architectural intentions, architectural quality and spatial detailing are aspects difficult to manage, why focus is often directed towards the measurable aspects of construction rather than the complexity of the home as a phenomenon and as spatial form intended to unfold experienced domestic architectural quality: For example; ensuring value through process management and evaluation in (Ballard 2000), customization/ standardization, product and process complexity in (Höök, Stehn 2005) and management and quality assessment approaches seem more tangible and obvious subjects (Vibæk Jensen, Beim 2006). Consequently my study of the above historical development of the prefabricated house has led me to doubt whether we should at all think of prefabrication as a 'productification' of the house if by product we mean a commercialization and a fashion. In referring back to the comparison between Gropius and Corbusier's initial encounters with prefabrication it is my observation that, as Corbusier concluded already in 1910 on experiencing Behrens' seeming capitulation to the industry, there is still a need to continuously reflect upon our roles as architects in this industry and most importantly to let architecture be the basis rather than a coincidence ascribed to flexibility and left for the inhabitants themselves to form. It is inevitable that the market is a condition of the prefabricated house and that "*products are trade on the market to satisfy the needs of people*" as described by Vogler (Vogler 2005 p. 65). Likewise the golden solution to the prefabricated house is surely to be found somewhere in between the quality of the unique form of the individual home and the flexibility of the system. However either way it is our responsibility as architects to remain critical in defining and revealing those needs. It is my claim that whereas a lot has changed since the dawn of the industrialized society the errand of domestic architecture and especially potential of the prefabricated house is still both individual and societal, in principle equaling the original Modernist vision of the modern dwelling as an architectural and democratic potential in developing modern society. A house, it is my claim, is responsible to its context as well as to its inhabitants and even though it seems attractive and frictionless to pursue a flexible system allowing for mass customization it has hitherto left the eventually produced house as monotonous constructive frameworks responsible of neither of its inhabitants' individual needs not its context. As Corbusier wrote to Ritter in 1910, trying to follow the market is seemingly not a sufficient mean in revealing the functional and emotional potential of the prefabricated house (Weber 2008 p. 77): Rather than continuing to imagine the prefabricated house as a car it might be fruitful to conclude that it is not, and instead focus on the peculiarities of the home itself including its necessary functional and emotional domestic architectural quality as a responsibility and as a base from where to constructively produce it. Hence, the above study of prefab history as well as of current research into this field has strengthened and motivated my idea to condition my studies on initially taking one step back and trying to map out the necessary domestic architectural qualities in order to arrive at an architectural 'definition' of what a home actually is. The result of this work can be studied in the theoretical part of the PhD thesis and has resulted in the development of a particular focus on the necessary ability of the building envelope itself to address the sensuous scale of furniture in providing such base, a theory which I am pursuing a test and application of in this particular case study. In this relation the above review of the prefabricated house can be said to articulate the general critique of the lack of spatial articulation and *interiority* of our dwellings which motivated the theory development: The general need to improve our ability to approach the general domestic architectural practice tectonically, exploiting its actual technical and economical constructive elements in providing *interiority,* is particularly articulate in the prefabricated economically feasible dwelling. With this observation, which has only been strengthened in the actual engagement with the field studies at Boel Living, I progress into the proposed presentation and discussion of these studies and of the attempt to apply the developed interior architectural theory in practice.

Chapter 4

IN THE FIELD

THROUGHOUT THE LAST DECADES there has been an increasing activity within the field of prefabricated architecture in Denmark, often referred to as a so-called neo-industrialization (Gram 2002). Especially within the field of single family housing, a number of companies offering prefabricated houses have entered the Danish market. These companies offer different standard houses, which are entirely or partially prefabricated and hereafter transported to the building site and assembled. Thus, the same house is reproduced at different locations for different users; hence in principle a context less houses. In line with the original modern vision of the prefabricated house, these prefab technologies are introduced with the intention to arrive at a cheaper, more effective production, and are naturally also introduced with the aim of offering an increased domestic architectural quality of the fabricated houses. Companies like ONV Houses, Hjem A/S, Boel Living and Qbes all produce(d) prefab houses from either planar of complete volume-element in a rectilinear formal language which is in principle suitable for such fabrication systems (ONV Houses 2009, Boel Living 2009, Hjem A/S 2010, Qbes Houses 2009). Also the Danish buyers seem to be reacting positively to this development, and in total these companies have succeeded in establishing a positive 'feel' to the idea of a prefabricated house amongst potential buyers, something which has inevitably also been one of the vulnerable points of the prefabricated house in its history as described by Vogler (Vogler 2005). Thus, in general there was room for optimism when I started my research into the field in 2006 on the Master's thesis and in 2007 in the decision to continue the cooperation with Boel Living into a PhD project. At that time a company named M2 had even launched a series of luxury prefab houses designed by esteemed Danish architects such as BIG, Dorte Mandrup Architects, 3XN, Schmidt Hammer Lassen etc. (M2 2011).

It was this context which this particular case study about Boel Living A/S sprang from in 2007. However, as we shall see in the following, a lot has happened within just a few years completely changing this context, changes which however have not made the case of the prefabricated house less interesting neither less significant. Consequently, I do find that these changes are crucial in discussing the results which have come out of the case study. As described in Chapter 2 this observation has caused me to choose a chronological presentation and discussion of the case study below.

4.1 Boel Living A/S

By the time I started the PhD research in October 2007 Boel Living A/S was a novel player on the Danish housing market who had just initiated production in the summer of 2007. As described in the theory development I had become acquainted with the company during my Master's thesis in 2006 where I had the opportunity to follow the early initiatives in the start up of the company, hence, parts of this introductory sections originate from those early investigations. Boel Living opened as a sister company to the company Hjem A/S, at that time an established company which had been one of the first to introduce a high degree of prefabrication in the Danish housing market. However, whereas Hjem A/S were producing single family houses from planar flat-packed wood frame wall, and roof elements assembled onto the foundation on site, the construction technology introduced at Boel Living was a volume-element construction where complete fitted room-sized elements, also called 'box modules' are simply connected on site. Also with regards to the product program Boel Living initially aimed at another segment compared to the limited and very specific program of Hjem A/S who at that time produced one single housing model in three different sizes aimed solely at private buyers. With the choice to produce both single family houses and row houses, Boel Living not only chose to address private buyers but also developers and housing associations. Through cooperation with Denmark's biggest architectural firm Arkitema A/S, Boel Living wished to produce good quality low cost houses, both single family houses and row houses, thus in comparison to Hjem A/S initiating a widening of the product program. With the choice to utilize volume element construction it was Boel Living's main strategy to introduce a hitherto unseen degree of prefabrication on the Danish market and hereby hopefully also a potential to strengthen the architectural qualities of the prefabricated house: Thus, in its point of departure unfolding an ideal case study for my research focusing on domestic architectural quality.

Strategy and products

In volume element construction the contents of the house are so to speak, an inherent part of the product as it is eventually assembled from only a few 'boxes' on site. In relation to the theoretical study of *interiority,* volume element construction unfolds an obvious potential to investigate the theoretically stated need to interrelate furniture and the spatial envelope with the technique and economy of construction: At a general level one can say that the potential of prefabrication is inversely proportional with the size of the house. It is an inherent architectural challenge to make the most of a compact space, constructing the house from as few elements as possible minimizing the transportation costs which inherently does not add to the eventual value of the house. This accounts particularly for volume element construction, as there is otherwise a great risk of transporting just 'air' to the building site. Simultaneously Boel Living's first product program designed by Arkitema and engineered by the Danish engineering company Moe & Brødsgaard A/S was intended as a series of rather compact 1 and 2 storey houses, intended to be suitable for both single family and row house developments. Ranging in size from 104 to 140 m2 these initial models were still of considerable sizes, however, in comparison to for examples Hjem's program which ranged from 163 m2 to 237 m2, the first Boel Living series represented an opposition to the otherwise general tendency of the Danish market which went and still goes towards bigger private homes (Jensen 2009). However, this particular focus simultaneously represented a specific possibility to develop relatively dense

‘Cityhouse’, the first housing model designed by Arkitema for Boel Living.

Production research at Boel Living, planar wall element, fall 2007.

areas with defined neighbor connections, a decreased energy use but also a decrease of costs making the private house achievable for a wider audience and potentially also for strengthening the domestic architectural quality of larger developments intended for housing associations for example. When seen in the perspective of the developed theory of *interiority* and intention to focus on the relation between furniture and envelope which I brought to the table as a participating researcher, this downscaling of the house likewise offered an immediate potential. The user segment was initially middle income families, but also young and elderly couples as well as the increasing number of singles. With the choice to produce houses which can function as both row houses and single family houses, Boel Living simultaneously aimed at sites in urban environments and with higher density than usual single family house areas. Hereby public and private relations likewise represented an immediate focus in terms of interior and exterior connections and demarcations of the individual housing units. In total the strategy and deliberate choice of the company to work together with architects and even to simultaneously invest in research as a means for achieving an exterior critique and discussion of means for development, was in every way a prosperous starting point for a fruitful development. The production flow was initially intended to grow from one house a week till one house a day within the first half year of production of the first Boel Living series.

Start up

During the fall of 2006 Boel Living made investigations on production methods and factory layouts concurrent with Arkitema's design development. Meetings concerning the project thus incorporated both architectural and technical considerations mostly with all involved parties present. Since Boel Living was an entirely new company, and had to build a new factory from scratch to initiate production of their first housing models, a number of possible construction systems were discussed before a decision was made. Based on the initial drawings from the architects, four constructional systems were tested in terms of required dimensions, economy and weight. The four systems were steel skeleton, wood frame, massive wood elements, and Paroc isolated panels mounted on steel frames. Despite the simplicity of the massive wood element construction and the Paroc plate system; these two options were quickly discarded. The massive wood elements because of expenses and heaviness and the Paroc system because the solution has not yet been adapted to housing projects, and were considered too mechanical in its expression. Hereafter the choice was between the two most common systems; steel skeleton and wood frame. The decisive parameter here, already from the beginning, became economy, why the choice fell on wood construction, though with a steel frame deck solution chosen in order to avoid humidity problems. Personally I did not participate in the design of this first series, however, I observed the process and made an independent study and design proposal for my Master's thesis based on these observations and hereby tried to understand the conditions for volume element construction.

At a general level the choice of volume element production preconditions a maximum element size derived from the size of the truck by which the elements are transported to the building site (in Denmark limited to a width of 4500 mm, a height of 4100 mm, and a length of 12500 mm). By introducing volume element construction Boel Living was determined to leave a minimum of work for the building site, and each element was thus intended to be fully detailed and equipped with interior and exterior finishing from the factory, i.e. only work related to assembly was to be done at the site. Each element must though not only be dimensioned to withstand loads found in the final assembled position of the house, but must also be stiff enough to be lifted on and off the truck, without these loads causing exterior or interior finish to crack etc. Factory handling and transportation thus generally requires a lightweight construction to ease the process, just as the production of prefab room elements also makes it preferable to cluster all technical installations in as few modules as possible to avoid detailing of all the modules for this purpose. Thus, there are a number of general preconditions to take into consideration together forming a framework for the architectural design, one could say, such as to minimize the number of modules and surface area and to cluster the installations. In the light of these general preconditions it is not hard to imagine how economical considerations have often caused the prefabricated house to end up as a truck sized box. The initial housing series presented by Boel Living A/S was a series of three housing types; a two storey house of 140 m2 called Townhouse, a two storey house of 110 m2 called Cityhouse, and a one plane house of 104 m2 called Flathouse. Architecturally the intention with these houses which all incorporated a courtyard was to challenge the regular boxes dictated by the production and transportation of volume building elements by organizing them displaced around this exterior courtyard space, see page 29. The resulting houses which were as mentioned intended for both single family and row house developments had an immediately attractive feel to them especially in the exterior which was indeed promising and new to the market. The wanton freedom of the Master's thesis, however, allowed me to critically observe and analyze the birth of this first series. The main conclusions hereof were that the excess surface area needed to create these rather complex courtyard houses could with advantage be transformed into an increased spatial detailing of both the interior and exterior spaces which were rather unarticulated, monotonously reflecting the boxed modules in their plan solutions as exemplified in the plan solution on page 29. Having the freedom to let architecture itself and the idea of *interiority* be my point of departure I was critical to the lack of detailing of the actual functional and emotional potential of for example the bath or the sleeping places and of the fact that these primary places of the house were simply associated with a desired number of square meters rather than discussed as sensuous details adding to the experienced domestic architectural quality of these houses: I was

disappointed to experience that such vital areas of the house were literally treated as hatched areas on the plan drawings to be equipped with standard elements. Rather I find it obvious that the incorporation of prefabrication and a reproduction of the same house would, if anything, allow us to develop a particular architectural quality in these places which would give character to the house. It was consequently one of my conclusions on the Master's thesis that especially in prefabrication, when reproducing the same house over and over again we would have the opportunity to design these details, to make them fit to the house. I was disappointed to see that this potential was left untouched and I was still also free to raise this critique without having to account for it in practice: One could rightfully say that this initial critique was hard tongued and that I was about to learn the complexity of the reality behind it, but as a start it landed me the attention of the company and the perspective of continued collaboration in a PhD position.

Strategy for the field studies

When initiating the PhD research in October 2007 the factory was fully equipped with a complete assembly line and the first houses were leaving the factory. The role which I took on as a researcher initially was that of an observer, and in agreement with the manager I began to spend around 2 days every week at the factory in order to study the relation between the economy and technique of construction in the production with the resulting domestic architectural quality of the houses built as suggested in the concurrent theory development. In continuation of the parallel theory development it has been the goal of the field studies to pursue an actual practical transformation of the economical and structural elements of construction into experiences of *interiority* within the particular practical context of the prefabricated house as described also in the above introduction. Thus, whereas literature studies were giving me an idea about the constructive and architectural challenges related to prefabrication, I had also realized that an in depth understanding of how the houses were actually constructed at the factory was needed. Consequently, I set out by rolling up my sleeves intending to acquire this knowledge with both eyes and hands. It has been the intention to let the research consider the specific situation at Boel Living as it was and to condition ideas for developments on the particular realm studied there rather than to envision ideal systems, technologies, materials and economies which were not within reach. Throughout the project I have kept this strategy as it has been my intention to study the practical realm of the prefabricated house rather than to dream about it in referring to Herbert's extensive study (Herbert 1984). From October 2007 I consequently initiated these observations in one end of the assembly line intending to observe and participate in the process from raw materials to on site assembly which simultaneously allowed insight into the process from the point of view of the workers, while simultaneously following the general decisions made by the involved architects, engineers and managers. The account for the field studies thus relies upon observations, participation in meetings and actual production which also evolved into specific experiments and developments which I will present and discuss in the following. I have included a series of photos and drawings on the following pages stemming from these studies in order to help visualize and document the course of events.

4.2 'Waking up to reality'

When initiating the actual cooperation with Boel Living, it is necessarily part of the account for the course of events that my practical experience with architecture was at that time limited as I had only just finished my Master's degree. Consequently, I approached the task with great optimism but as I was about to experience also a slightly naïve idea about how smoothly this practice runs; it was in other words still intangible to me. Inside the factory planar wall, deck and ceiling elements were constructed from wooden frames which were then insulated, assembled into volume elements, clad with a selection of façade materials, and finally transported to the building site as envisioned. The factory was divided into four main sections; one for preparation of raw materials, two for production of planar wall, deck and roof elements and a final section for assembly of the planar element into volumes. Each of the production sections were built up around a linear assembly line which was supplied with raw material and one end, which were then connected into wooden frames, insulated, fitted with interior and exterior surfaces, before being dropped off in a transportation track. These sections were then connected by a transportation track, which transported the planar wall, deck and roof elements to the last section, where they were assembled into complete volume elements and clad with interior and exterior finish. In this last section interior fittings, such as toilet/bathroom, kitchen, technical installations etc. were likewise installed. However, it instantly became clear to me, as I initiated the field studies in the section for production of wall elements that the reality is more complicated than the usual diagrams which have been utilized for over century now to depict the smooth production and assembly of the prefabricated house.

Production research

On setting foot in the factory the first thing that sprang to my mind was how complex and manually dependent the production was despite utilizing state of the art equipment. One thing was the buildup of for example a wall, which is in itself quite effective as the initial assembly of the raw wooden frame with insulation, front- and back sheathing is in its basic form quite simple and can potentially be highly effective and automated. However, as installations, door and window holes interior and exterior finishing, the matter easily becomes less simple and craft dependent, as it can be seen on page 30. I have used the wall as an example here, but the same issues apply to deck and roof elements. Deck, wall and roof elements were all produced in the full size of the eventual volume element and hence simultaneously functioned as stabilizing

Production research at Boel Living, assembly of planar deck, wall and roof elements into complete volume-elements, fall 2007.

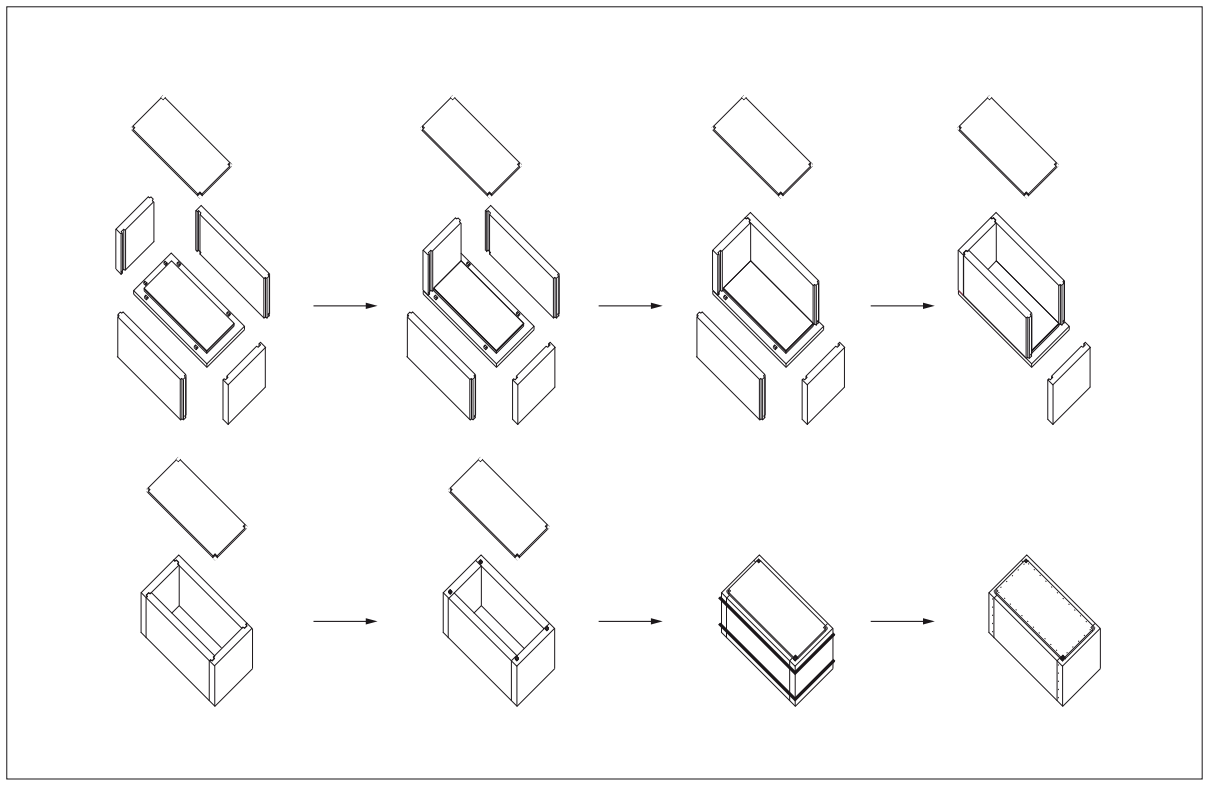
Production research at Boel Living, transportation and on-site assembly of complete volume-elements, fall 2007.

'Squarehouse' the second series of houses designed by Arkitema for Boel Living in the spring of 2008.

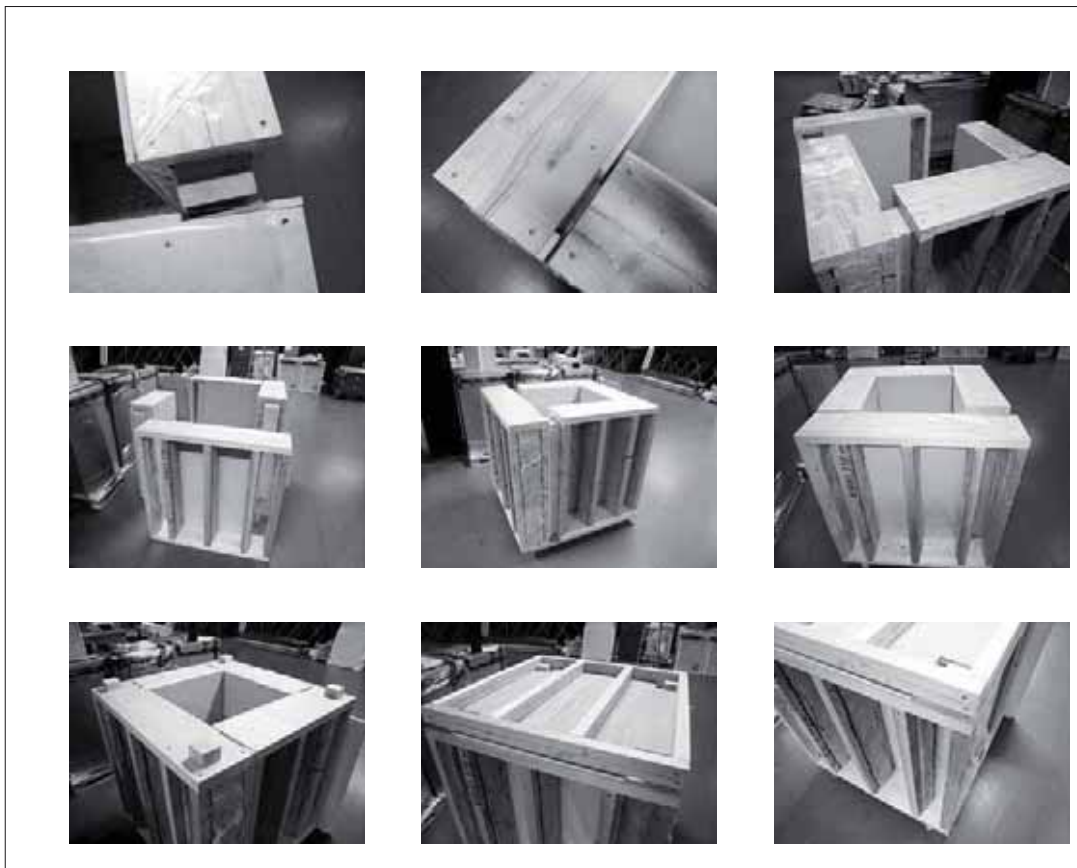
plates and shear walls during transportation as well as in the finished house, in its point of departure a logical and simple principle. However, in addition to the challenges mentioned related to the 'fitting' one could say related to the production of the individual planar deck, wall and roof elements the actual assembly of these elements into volume elements proved to be the true challenge in initiating the production at Boel Living and in achieving the necessary flow in the production.

At a general level we were haunted by tolerances. In the first instance of the raw materials themselves, in the case of which we had to face the fact that even in a controlled factory production tolerances is a big issue. Not only did we have to find it to our costs that beams are not straight, not even steel beams coming directly of the plant, and that the tolerances of the raw materials can add up during the initial production of the planar deck, wall and floor elements and consequently causing serious challenges when the assembly of the planar elements into complete volume elements it to commence. Here the actual joining of these planar elements proved a major challenge due to these tolerance problems. As the wall elements were connected to the deck element and the roof element was finally installed as the 'lit' of the complete volume-element, it often either left gaps to be erased in the interior or was too big and had to be adjusted, just as the walls themselves left similar visual traces of the tolerance problems. Because of the lack of steering mechanisms indicating the correct positioning of the walls in relation to each other the assembly sometimes had to be redone to fit. After the assembly interior paintjobs simultaneously often had to be redone, just as the initial choice of 'screen brick' for the exterior façade proved a major challenge as it exposes every slight inclination and tolerance without mercy. Likewise the first encounters with the transportation and craning in place of the completed volume elements on site proved more challenging than first anticipated. With regards to transportation our initial experiences showed that the actual truck loading, road trip, and eventual craning often took its toll on the elements as road bumps, loading and off loading easily caused damages to especially the corners of the elements and also caused cracks in interior finishing. The major challenge, however, proved to find its expression in the actual jointing and tightening of the modules. Especially where the interior spaces cross the modules and the module joints are therefore exposed proved a visible and tangible challenge which cannot be erased as it was the initial strategy. The vision of achieving a fluent connection of the spaces resulting from the different modules in both interior and exterior without visually 'giving away' the fact that the house is constructed from modules proved impossible to achieve despite all the effort with paint and plaster. Thus, in both the factory assembly of planar elements into volume elements and in the eventual connection of the individual volume elements into a complete house on site, the actual jointing proved to be the crucial point, see page 33 and 34. However on the positive side we also found proof that it is actually possible to crane, assemble, and close an entire house in one day, which is indeed a promising finding. Transportation is however either way an expense which is in principle 'invisible' in the end product, and must therefore be reduced as much as possible. In this regard the initial house consisting of 6 volume elements and hereby 6 truck loads proved an expensive solution.

In comparison with traditional construction our initial experiences showed that the modularization which lies at the core of prefabrication is a necessary point of departure and a significant challenge which should be developed as an integral part of the production and construction as well as of the architecture of the eventual house departure rather than taken for granted. In many ways it became clear that the production line at the factory, the constructions designed by the engineers and the design of the actual house done by the architects was far from integrated. Actually the production, the construction and the architecture of the house seemed to be fighting each other. Rather than letting the necessary joints add to the quality and character of the house we were trying to erase them, stubbornly expecting everything to fit. A lot of work was done to erase the sign of the production process which were intended as a seal of approval, of a controlled factory production, but instead of cultivating these signs everything possible was done to minimize them; to mime the visual appearance of the 'ordinary house' one could say. Consequently a lot of excess work had to be done and often redone in this phase of assembly causing the production prices to increase significantly compared to the budget, and in order to gain control of the expenses the company was forced to call back the architects to change the design of the initial housing models already in April 2008. The complexity of the first design which was as mentioned a two-storey house of 140 m2 consisting of 6 volume elements had in many ways been to ambitious a project to start out with, as the technology which we were using was new to everybody; to the managers, to the workers, to the architect and even to the engineers. Of the 6 modules 3 included baths and kitchen and thus installations had to be connected between these modules which proved an additional challenge on site. Likewise the house had a high surface to volume ratio and the modules were small compared to the maximum allowable size and therefore did not optimally utilize production facilities or the transportation which took 6 truck loads as mentioned above. Held together with the additional tolerance and assembly issues which were causing challenges and excess production expenses even in the production phases which took place under the protecting roof of the factory, it became clear that a more integrated design process had to be facilitated. It is perhaps needless to say, but already at this point the initial architectural vision and level of detailing which was already in the first houses produced mainly a question of exterior treatment was beginning to slip into the background, as the need to gain control of the production expenses became crucial.



Sketch for a new assembly system incorporating groove joints capable of obtaining tolerances, winter 2007/2008.



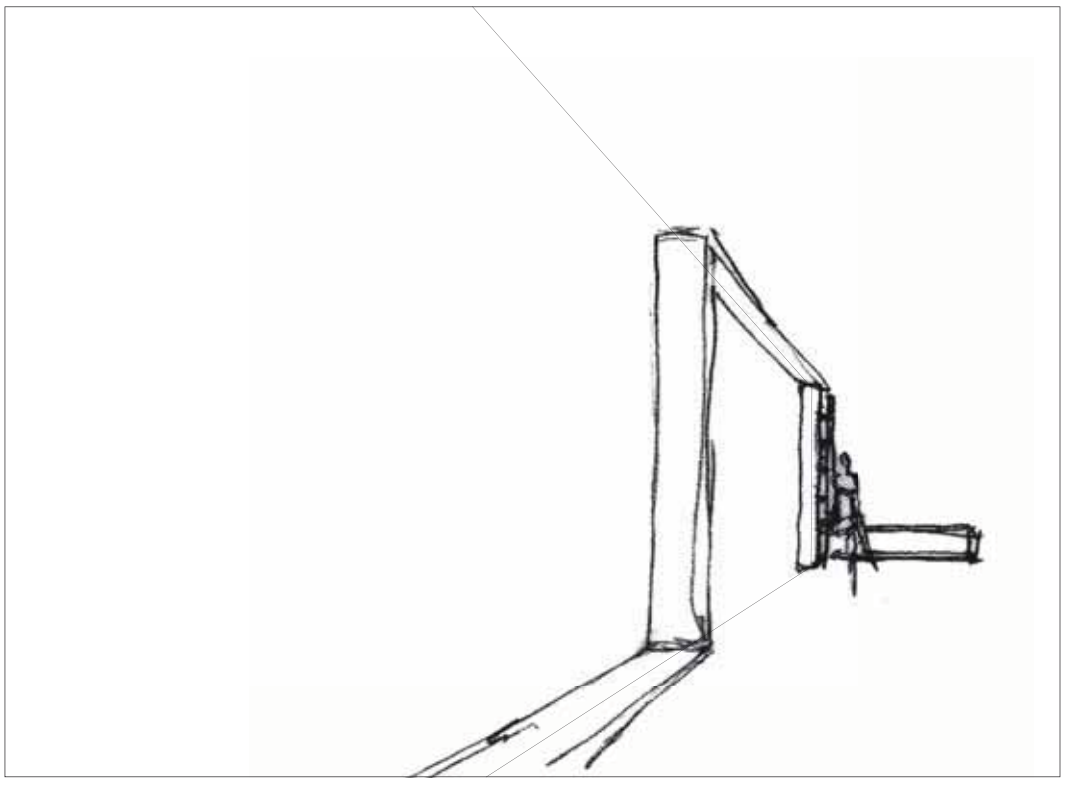
Wooden prototype of new assembly system incorporating groove joints capable of obtaining tolerances, winter 2007/2008.

In relation to the PhD research I began to gain practical understanding of the challenges of the prefabricated house, and also of the implications of my initial critique and call for increased *interiority*. As I was able to link the observations of the field studies to the literature studies I was doing into the history of the prefabricated house, I gradually discovered the significance of for example Vogler's statement that prefabrication often ends as a traditional construction taking place under a roof (Vogler 2005). Whereas some of these challenges were most certainly child hood diseases which were gradually overcome it became clear that the observed challenges, particularly those related to joints and tolerances simultaneously represented some of the general and persistent challenges which for example Konrad Wachsmann had likewise been struggling intensively with, as accounted for by Herbert (Herbert 1984). A part of these initial problems can be ascribed to the fact that rather than developing the 'products' in-house from design to production the choice to hire architects and engineers for partial orders so to speak proved insufficient. I am not claiming that architects nor engineers, managers or workers were doing a bad job; rather, it is my observation that it was the setup of the cooperation which was unsuccessful from the beginning. It was certainly daring to start such a project from scratch, but at general level that was not the main source of the problem, which it is my claim lies in the process. As mentioned above the architects' design of the first houses was done concurrently with the choice of construction and the laying out of the production line, which is in principle what can be desired from an architectural design process which is in its essence multidisciplinary and should therefore be integrated. The problem, however, lies in the details within which it was carried out, it is my observation: The architects were developing their designs in plans and sections as is their usual media, likewise the engineers were using sections to visualize their construction details, thus, in principle using the same means of visualization as in traditional onsite construction. Simultaneously the production line at the factory was being made ready where the workers would in short experience that the information they needed was not to be found on these drawings. In traditional construction the carpenter or the bricklayer knows how to go around a corner and he can read how to detail the construction around for example a window from plan, section and façade drawings. In volume-element prefab production the usual conventions for how to go around a corner are however completely changed, we began to understand through the field studies. Rather than evolving as a continuous adding of materials and adjustments, each deck, wall, and roof element in volume element construction must necessarily be defined independently and in terms of how it is to be connected to the other parts. Here each corner defines a jointing of two planar elements, together forming a system which can be compared with a set of giant LEGO blocks in which the block itself cannot be adjusted continuously; it must fit precisely. Hence, the process under which the first houses came into being was actually quite similar to the one which goes before a traditional construction and consequently the technical drawings and joint solutions were likewise similar. Furthermore, in expectance that everything would work, nobody had taken the time to do some mock ups and actually see, and not to mention try out, how the usually envisioned diagram of a smooth assembly of planar elements into volume elements ready for on-site assembly would actually work. We had somehow taken for granted that what we usually do on site would automatically become fast, cheap, precise and effective under the protective roof of the factory. Instead what we experienced was that it was rather causing more challenges. In retrospect the course of events was already at that initial phase not without parallels to some of the failed prefab ventures which are a part of the historical study of the prefabricated house above. With the words of Vogler, one could say that an overall industry organization was lacking, tasks and working areas among project parties was confused eventually affecting the mood and pride of the workers (Vogler 2005 p. 111). It is my observation that especially the 'distance' one could say between the action at the factory and the external architect and engineers was causing huge problems. Both architects and engineers had in principle already finished their tasks, but the fact that things were not working at the factory proved that they were still needed. Not only had their solutions to the tasks given proved unfitting, it became clear that from A to Z what had been needed and was still needed was for every aspect of the product to be conceived in-house in a more integrated fashion, akin to the process signifying the quality of the car.

However already at this point time was running and the investment put into the company was likewise drastically increasing without having reached a significant production flow. Thus, even though we had reached the conclusion that there was a need to develop a more integrated solution, something had to be done immediately. Consequently, a series of new housing models was launched in April 2008 as mentioned above. In order to meet the need to cut down the production expenses these houses were based on an economically more optimized utilization of the volume elements; hence the number of elements forming each house was cut down and hereby likewise the surface area, see page 35. In terms of the PhD research and that of increasing the *interiority*, the detailing of these houses came out quite similar to the first series, already at this point the initial vision of offering a hitherto unseen architectural quality at a low price was pushed in the background in order to gain foothold. Except for the admittance that the module joints had to become a visual part of the interior no significant architectural changes were made to the interior detailing. However in general the number of types of houses was increased in order to attract a wider audience, hence now including everything from student- to family housing, but derived from similar elements, see page 35. Personally, I did not take part in the actual design of these houses. Rather I had become absorbed in trying to understand the constructive principles of prefab production and was convinced that architectural improvements are preconditioned by such understanding. In a group counting the production

manager, a couple of production workers and myself we initiated a concurrent production study intended to solve some of the constructive challenges which the initial field studies had uncovered. One of the conclusions drawn from the field study was that the workers were missing precise principles for how to manage the assembly process. In participating in the assembly process at the production line I had observed that some of the challenges related to the assembly of planar elements into complete volume-elements had to do with actually finding the right positioning of the elements in relation to each other. If continuing the parallel drawn above to LEGO blocks, one could say that the little round dots which function as 'steering mechanisms' were missing, hence the big deck, wall, and floor sections were easily offset and misaligned during assembly. Consequently we were working on trying to incorporate such 'steering mechanisms' into the construction which could control the positioning of the planar sections in relation to each other. In continuation of the discovered challenges concerning tolerances we were likewise trying to utilize these 'steering mechanisms' as a means for obtaining tolerances, and came up with a system for how a series of longitudinal grooves and recesses could be integrated directly into the wooden I-beam based planar elements. By allowing these groove joints to be loose enough to obtain tolerances easing the assembly by unfolding a constructive system which allowed for a loose assembly of all the 4 wall segments on the deck element and the addition of the roof section as the 'lit' before simply tightening the whole 'box' module with straps as exemplified on page 37. In this way the geometry of the assembled 'box' ensures a general precision where tolerances are evened as opposed to the initial system, where one wall after another is installed with a high level of precision in which tolerances could add up making it impossible to fix the last wall or the roof section. In order to test these principles we fabricated simple small-scale prototypes (2x2x2 m houses) which were then discussed with the external engineers in terms of structural soundness and with the production workers in terms of working routines, see page 38.

Through this dive into the actual engineering and production technology of the prefabricated house I began to look at the envisioned task of improving the domestic architectural quality, the *interiority* of the prefabricated house, as consisting in two separate but also corresponding parts: First that of understanding the construction system underlying the spatial envelope itself and achieving an effective production of the basic framework which can be seen paralleled in Werner Blaser's precise furniture system exercises also discussed in Chapter 6 of Volume 1 (Blaser 1985, Blaser 1984, Blaser, von Büren 1992). Ideally a simple and effective general construction system would allow for the expenses saved to be transformed in an increased architectural freedom and level of detailing in terms of interior and exterior furnishing of baths, terraces, reading niches etc. However, I also began to realize that probably this calculation would not be as simple as that as I observed how everything which can be cut away is most likely cut away if not in the production itself, then in the encounter with developers wanting to optimize their profit. Thus, secondly there is ultimately a need to develop this sensitivity and detailing directly within the actual jointing of the structural elements themselves as argued in the theory development concerning *interiority*, and as it can be said to be inherent in Gottfried Semper's early tectonic references to the construct as a soft dressing of the human body emanating in textiles (Semper 1989; 1851, Semper 2004; 1861). In continuation hereof I had also initiated work in the spring of 2008 to develop a principle for actually utilizing the problematic module joints between the individual volume elements as space dividing and furnishing element in itself, an idea which I will return to later. However in the first instance action at the factory was dependent on an increase in the production flow and thus in developing the basic envelope system which simultaneously also became the focus of the first research paper.



Sketch for an actual spatial and furnishing utilization of the crucial module-joints, winter 2007/2008.

Paper 1:

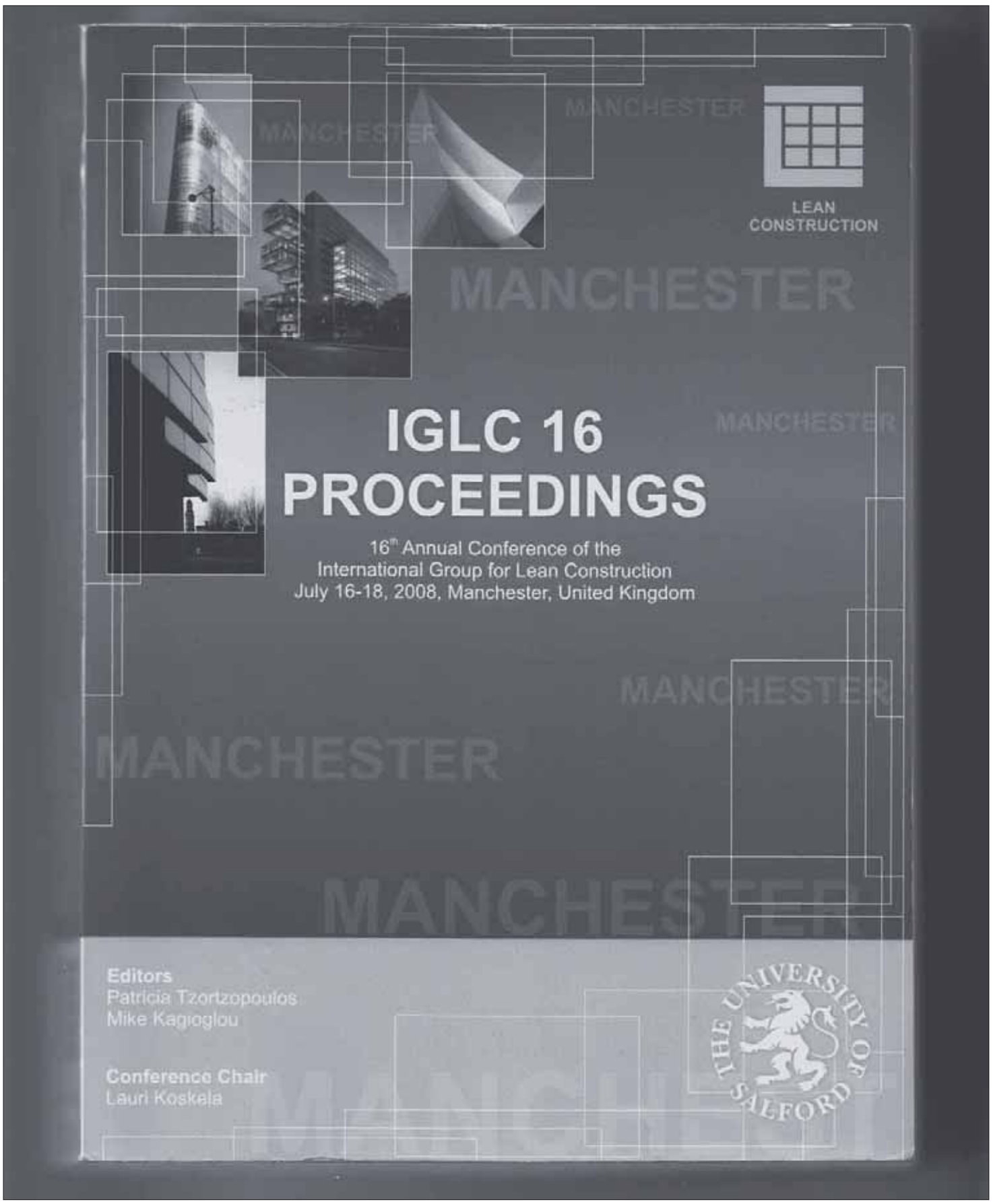
'ARCHITECTURAL INTENTION AS THE MEDIATOR OF LEAN HOUSING CONSTRUCTION'

Published in the proceedings of the 16th Annual Conference of the International Group for Lean Construction, Manchester, UK, July 2008

The first of the selected papers in many ways represents my initial eager to try to understand the constructive and production technical conditions at the factory. The case for the paper was as mentioned the initial field studies done in the fall, winter and early spring of 2007/2008 accounted for above. These studies had in a way both strengthened the need for a more direct and active involvement of the architect in the construction processes eventually defining the framework so to speak of our architectural ventures for which I had argued in the theoretical part of the thesis, but simultaneously they had also shaken by initial picturing of the conditions signifying the revelation hereof: I was shocked and provoked by the fact that architecture, construction and production had seemingly been conceived as three independent parts expected to fit and consequently I wanted to discuss the architects' role in such processes at a general level. I was beginning to find evidence that there is a need for us as architects to assume a more active if not even leading role within these processes. However, I had also gained respect of the underlying conditions for this call and had consequently turned my attention, as did Konrad Wachsmann, towards construction and production techniques. In order to relate the observations stemming from the initial field studies and the envelope prototypes produced to a general production context I began studying production theory, herein especially the development originating from the car industry which was originally the case for the vision of the prefabricated house.

In studying the principles of lean production which has found its expression within construction in the establishment of the 'International Group for Lean Construction' I began to discover possible links between these theories and the observations done in the field studies, but also links back to the architectural critique which I had initially put forward in studying the history of the prefabricated house. The discussion of the 'value' of the product being produced and the need to eliminate all elements of the production which do not eventually add to the experience and 'value' of the end product which define the core of lean theory allowed me to reconsider the parallel between car and house by introducing an architectural discussion of what the 'value' of a house actually is into the lean principles (Ballard 2000, Howell 1999). The resulting paper was eventually published in the proceedings of the 16th Annual Conference of the International Group for Lean Construction held in Manchester, United Kingdom in July 2008. It is a curiosity worth mentioning that in participating at the conference which in principle discusses how to maximize the 'value' of construction (which I would say is inevitably an architectural question), I was one of not even a handful of architects among 300 participating researchers! Otherwise the field is dominated entirely by production engineers as mentioned earlier. The paper was accepted within the championship entitled 'Prefabrication, Assembly and Open Building' in which it was characterized in the following way by Glen Ballard who is co-founder of the International Group for Lean Construction. *"The most provocative paper is clearly Frier et al.'s 'Architectural intention as the mediator of lean housing construction'. The authors propose that the architect serve as the guardian of customer values that can perhaps be encapsulated in the expression 'feel'. This effort to bring architects and architecture into the lean community can only be applauded and readers are urged to engage in the conversation. One might ask for more specifics regarding the architect's role in the project delivery process, explore technology for better ways of presenting design options to customers, and ride the analogy between cars and houses into speculation about what the future holds for the tension between customization and efficiency. Can we have our cake and eat it too?"* (Ballard 2008 p. 519).

As architects we often criticize other project parties for not understanding the quality and significance of architecture and for killing our spatial ideas. However, if turned upside down we cannot expect for architecture and spatial detailing to automatically be positioned at the center of constructive and production technical developments if we refuse to understand the particular constructive and production technical conditions and particular 'language' spoken by these other project parties as discussed also in Chapter 6 of Volume 1. The venture into construction and production technique at the factory and the relation of the observations made there to the terminology and principles of Lean Construction opened up a potential for how to initiate a practical description of domestic architectural quality by means of the constructive elements of the house at the production line. However, as it lies implicitly in Ballard's final question of whether we can 'have our cake and eat it too?' the vision of uniting home and production system, which lies at the core of the proposed positioning of *interiority* as a critical means in practice, is also idealistic. Both in terms of product and process Ballard's question is inevitable: With regards to the process there is most certainly a need for architects to increase our involvement with the industry, however, on the other hand we cannot embrace the entire process in detail. With regards to the product, as I have already touched upon previously, the development of a highly efficient system for producing the basic building envelope for example, does not necessarily entail room for increased architectural detailing as stated above. Imagining an integration of the production system and the intimate *interiority* of the spatial detailing signifying domestic architectural quality as insinuated in the theory development, is inherently an ideal conception; a dream. Having our cake and eating it too, entails a fruitful cooperation which all parties should be interested in, but which is not easily achieved I was beginning to realize. I however, had not gotten tired of discussing the architects' role in this matter. Actually the acquaintance with Lean theory had filled me with renewed hope not to mention a vocabulary for engaging in dialogue with the other project parties; I had the feeling that I was slowly getting a grip of the prefabricated house.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ARCHITECTURAL INTENTION AS THE MEDIATOR OF LEAN HOUSING CONSTRUCTION

Marie Frier[1], Poul Henning Kirkegaard[2] and Anna Marie Fisker[3]

ABSTRACT

In recent years a number of companies have taken up the challenge of producing prefab houses using *lean* principles, hereby incorporating *value* driven production theory as the means to optimize construction processes. However, the *value* of home is dependent on architectural qualities and interior spatial experiences difficult to operationalize as production objectives. As stated by Sven Bertelsen a home should be more than the sum of the parts; the home constitutes our physical and metaphysical being and there is *deep feelings* connected to this phenomenon (Bertelsen, 2005).

Modularization and prefab production as *lean construction* strategies hold obvious potentials in the development of an effective building envelope with regards to indoor climate, assembly etc. However, the discussion of lean construction, future working co operations and processes, often avoid an actual positioning regarding the *values*, which were originally the main focus of *lean construction philosophy* (Howell, 1999). Through the development of a particular interior architectural focus this paper suggests a method for reintroducing customer *value*; architectural quality, as the outset for making housing construction lean.

KEY WORDS

Prefabrication, architectural values, construction strategies, theory and application.

INTRODUCTION

With the automotive industry as a role model prefabrication is generally considered to improve *value*, by reducing complexity of construction, minimising errors and lowering production expenses (Lessing, Stehn and Ekholm, 2005). Since Le Corbusier introduced his 'machine for living' a century ago architects and companies have pursued the idea of developing good quality low cost industrialized houses. However, instead of unfolding increased architectural values the industrialized house has remained architecturally uniform and poor in spatial and material detailing. The units set into production have continuously become only a shadow of the many architecturally iconic and expensive prototypes developed (Davies, 2005:11). The matrix of uniting potentials of lean construction theory and

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interests of different parties in developing architecturally stimulating *homes* is though practically difficult to solve. This is reflected in the current discussion of prefabrication as a lean construction method. Here focus is often on the measurable aspects of construction rather than the complexity of *home* as a phenomenon; ensuring value through process management and evaluation in (Ballard, 2000), customization/standardization, product and process complexity in (Höök and Stehn, 2005) and management approaches and quality assessment approaches in (Beim and Jensen, 2005). Thus the establishment of prefabrication as a lean construction method is a complex concept which Björnfot and Sarden have been trying to clarify, concluding that there is still a need to precisely specify customer value in lean construction (Björnfot and Sarden, 2006: 275). In continuation hereof workflow, and the role of different parties is a heavily debated area of lean theory treated by Koskela, Ballard and Tanhuanpää, 1997 amongst others. But how can value be defined with regards to the house and who is responsible for developing these values?

In the house, the experienced *value* is dependent on spatial articulation. The experiences which we cherish and which become lasting memories often occur in the specific *interior* treatment and detailing of architecture. This could be for example a window which is not just a window but also a place to sit, read and enjoy the view. Thus, when reconsidering *value* for the customer as suggested by Björnfot and Sarden, the intangible concept of *architectural quality* must necessarily be part of such reconsideration. This paper takes its starting point in architecture and how a positioning of architectural qualities within the technical framework of prefabrication can contribute to the values of lean housing construction. Through a specific case study, an ongoing research project carried out in co-operation with the Danish housing manufacturer Boel Living, the paper explores the potentials of using architectural intention as the theoretical and practical mediator for transforming production, constructions and *values*. Hereby an increased involvement of the architect in the formulation of specific endeavored architectural values and in the actual development of modules, joints, tolerances and spatial details is suggested.

LEAN CONSTRUCTION AND INDUSTRIALISED HOUSING PRODUCTION

When Engineer Ohno began developing lean strategies it was with the intention to reduce the time to develop and deliver a new model, why the production processes was considered along with the design of the car. In opposition to Henry Ford's 'flow based' strategy Ohno started focusing on customer orders; a '*value* based' strategy (Howell, 1999). Thus '*Value can only be defined for the critical costumer and is only meaningful when expressed in connection with a specific product.*' (Bejder, 2005:34). Theoretically Ohno wanted to be able to adjust each car according to customer needs.

With prefabrication the house is adopting some of the characteristics of the car, especially in volume element production, which is the subject of this paper. Here production is systematized into elements of a high level of prefabrication. However, fitting the home into an industrialised production causes complexities in terms of both technique and architectural qualities. In the following a number of these complexities are listed and formulated on the basis of a study of the ongoing production at Boel Living. The purpose of the study has been to expose streamlining potentials both with regards to construction techniques and architectural qualities. Boel Living, established

in 2007, is producing timber frame volume elements, aiming to offer a series of fully detailed single family housing typologies of high *quality* (Boel Living, 2008).

Technically new joint principles are required to achieve a tight building envelope meeting the increasing building code requirements. Material tolerances need to be considered and modes of assembly are to be integrated into the construction system and logistics. Architecturally, volume element production results in a number of limiting conditions regarding dimensions, shape which is conditioned by the chosen construction system (in this case timber frame construction), and adaptation to site which is in the case of Boel Living limited to orientation. These conditions are similar to the ones of the car; roadwidth, joints, safety etc. Still though we do not think of the industrialised house as we think of the car, especially the users are often sceptical of buying a "ready to wear" house. What differentiates house and car?

The car is a highly specific product, expressing an identity; a SMART, a Volvo or a BMW (Björnfot and Sarden, 2006). Consequently the design qualities of the car, are consistent regardless of the individual choices made by the customers. The customisation level does not disturb the overall architecture of the car or, one might say the identity and design intent; it is limited to changes of colour, interior fabric, motor specifications etc. If looked at as architecture the car would be considered a "gesamtkunstwerk" (Frampton, 2001:59.); a total work of art where every design detail has been determined as part of the whole; a whole which is the responsibility of the designer. With reference to Bejder, cited at the beginning of this section the specific shape and detailed design of the car is the foundation for making its production lean as well as for the appreciation of its design; its *values*. In case of the house in contrast, we are discussing and expecting a completely different level of customization, a flexible system of walls allowing the user to design freely, leaving manufacturer and architect without responsibility for the actual qualities of the house. Hereby the house is loses its specific shape and if following the above; its *value* and the motivation for lean production. Consequently there is a need to reconsider the parallel between car and house; does flexibility equal architectural quality of the house and what are the actual *values* of home; the values which according to Greg Howell should be considered the outset construction philosophy? (Howell, 1999)

AN INTERIOR APPROACH TO ARCHITECTURAL QUALITY AND VALUE

In its origin architecture is a multidisciplinary profession which requires the skills to balance technical-scientific, experiential-artistic and societal-contextual aspects. Therefore the question of the architectural quality of the house is closely related to the question of the architect's role, -how we approach the field of architecture. When Le Corbusier formulated his architectural vision for the 20th century 'machine for living', it was highly motivated by technological breakthroughs (Corbusier, 1923:137). But despite his proclaimed goal to develop a replicable model, he did not evade to develop this model from a specific interior spatial intent. His Unité apartment is a characteristic inhabitable interior, almost a piece of furniture offering different specifically designed spatial experiences of *home* to the customer. Today one parameter seems to dominate most discussions on the subject of desired qualities of the industrialized house: flexibility. However, often the users actually have difficulties managing the choices provided by the resulting open plan solutions

(Mortensen et. al, 2005:12). Instead of experienced value the spaces are without characteristics, spaces which the users do not identify with as dwellings. When held together with the actual circumstances of lean construction treated above, the strive for flexibility has resulted in a lack of development of the actual spatial possibilities of volume-elements. In prefabricated houses the plan often follows the module lines, resulting in interior uniformity (Frier, 2007:38). In this way especially interior qualities are ignored; contents and hereby *values* are left out even though with volume elements there is evidently an unexplored potential for the architect to address the interior beyond the standard insertion of the toilet core and slavish interior accept of the boxed framework. In addition the prefabricated house is without context. Identical houses are reproduced on different locations and thus cannot gain their value from a specific relation to site; so what is the possible *value* of the industrialized house?

"We give shape to the house and the house gives shape to us" one can read from Andrew Ballantyne's '*What is Architecture?*' (Ballantyne, 2002:2). Following this line of thought the house whether industrial or not, has to be approached with the immediate relationship between architecture, user, and architect as the starting point. Consequently, the *value* of home is dependent on specific *intended* interior experiences. According to American architect and theoretician Marie-Ange Brayer, a chair, a carpet, a bed etc. are immediately inhabitable due to their proximity to the human body (Brayer & Simonet, 2002:42). Following this line of thought one could say that furnishing; the points were architecture twist, folds, or bends to create specific experiences signify our experience of home. The ability of architecture to furnish a place simultaneously defines the area of contact between the architect's spatial intentions and the identity of the inhabitant. Herein the experienced *value* of the house is revealed: the interior defines *home*. Inspired by the classical conception of architecture understood as furniture, proposed by Le Corbusier among others, a novel design strategy, for the future industrialized house is hereby suggested. But what are the conditions of this necessary interior empathy governing house in the context of lean construction? In the following the conception of architecture understood as furniture is sought adopted as a perspective through which to challenge construction strategies and the role of the architects in lean construction processes.

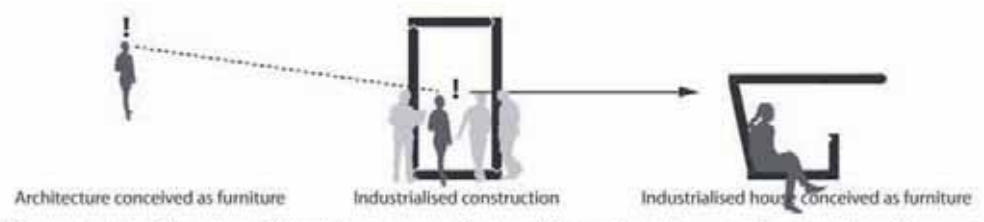


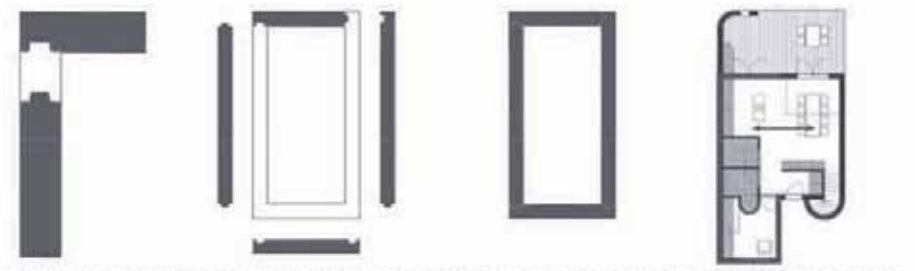
Figure 1: Architectural intention as mediator of construction- and value development.

APPLICATION, ARCHITECTURAL INTENTION AS MEDIATOR

Often communication between engineers, architects and manufacturer is broken off when production is initiated. At Boel Living this has been the case and the first houses are being produced from drawings made in the planning stages, in need of further development in order to streamline production. In continuation hereof and in

line with the above theoretical study, the research project has methodologically developed into an action-oriented experiment, investigating whether an architectural involvement in the product optimization process can help increase the architectural *value* potential of future housing series. Thus the mentioned production research has been followed up by research concerning development of details and assembly systems which are naturally of the greatest challenges for a new company. Here the intention has been to use the conception of interior and furniture as a *value* generating perspective in the development of construction details.

The quality of furniture with regards to both perception and production flow is the detail; the detail is decisive for the flow of production and for the *feel* of the chair. At Boel Living the greatest challenge so far has been related to the tolerances and assembly problems concerning the flow from planar elements into volume-elements. With the detail as the focus point the action based research has taken its starting point in participation of the architect as the means to familiarize with construction, production and the problems at hand. This field study and the theoretical idea of the connection between architecture and furniture have resulted in the development of a proposal for a new assembly system incorporating a groove system securing precise assembly and adjustment of tolerances. With the groove system all planar elements can be raised, pulled together and fixed with screws with no further adjustments needed, securing a better production flow. An optimization of detail and assembly simultaneously holds a potential for a higher degree of architectural freedom. In line with the intention of developing a furnishing architecture and improvement of assembly technique opens up for the development of interior and exterior furnishing contents within the volume elements. With an optimized basic envelope system a more free approach can be adopted in the interior independent of exterior walls and module lines offering articulated kitchens, intimate baths and enjoyable embracing window corners adding to the *value* of the house, like the detailed interior of a car. Hereby novel interior qualities are suggested in the industrialized house through the utilization of technologies and production methods attributing to form and decoration and hereby to our sensuous experience of *home* as illustrated below.



Groove joints allowing easy module-assembly and hereby a more free interior detailing; embracing corners and open sequences

Figure 2: Architecture conceived as furniture in detail and entirety.

CONCLUSIONS

This paper has outlined that a strong connection between theory (of architecture and of construction strategies) and practice is needed in order to improve the value of the industrialized house and make it suitable for lean construction. In line with working-constellations in the automotive industry, the research suggests that an

architect working in-house now more than ever has the opportunity of becoming an advocate for *value* and for performing a quick adaption of the product for different sites and user-groups. Hereby a potential to develop specifically designed furnishing architectural elements within the technical and economic framework of volume element production; a kitchen which extends onto an outdoor kitchen furnishing the terrace, a window-seat, or a bath with a view etc. Simultaneously this approach offers a potential for reinforcing the exterior site-relation of the industrialized house by using furnishing elements to establish a dialogue between house and surroundings.

Through a reevaluation of the origins of lean production; the car, and the concept of *value* in the context of *home*, a method for reintroducing customer *value*; architectural quality, at the center of lean construction strategies has developed. This reevaluation has been strongly motivated by a specific positioning regarding architectural quality rooted in an interior furnishing conception of architecture. Hereby it is suggested that architectural intention can become a mediator for uniting different perspectives among lean parties into a joint venture pursuing the *values* of constructing and living in industrialized *homes*.

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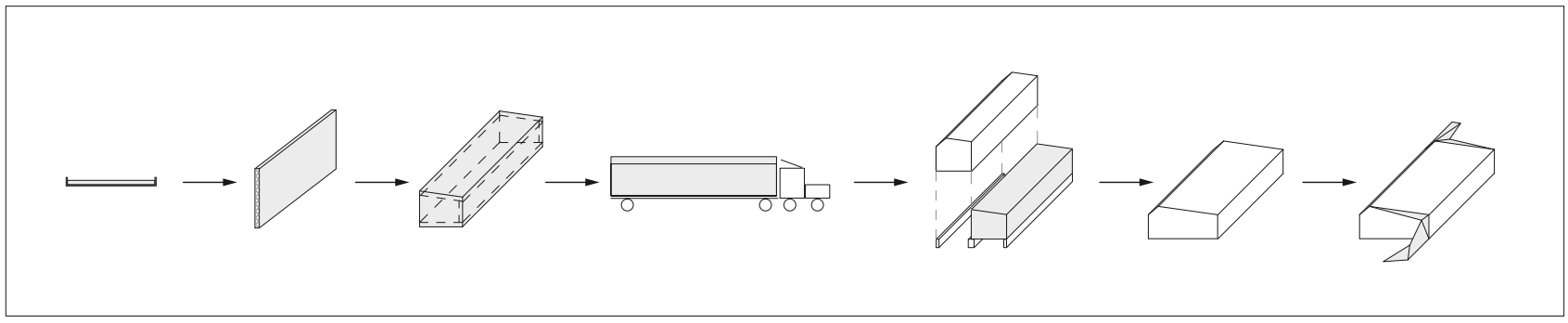
4.3 *'Getting a grip or getting lost in construct?'*

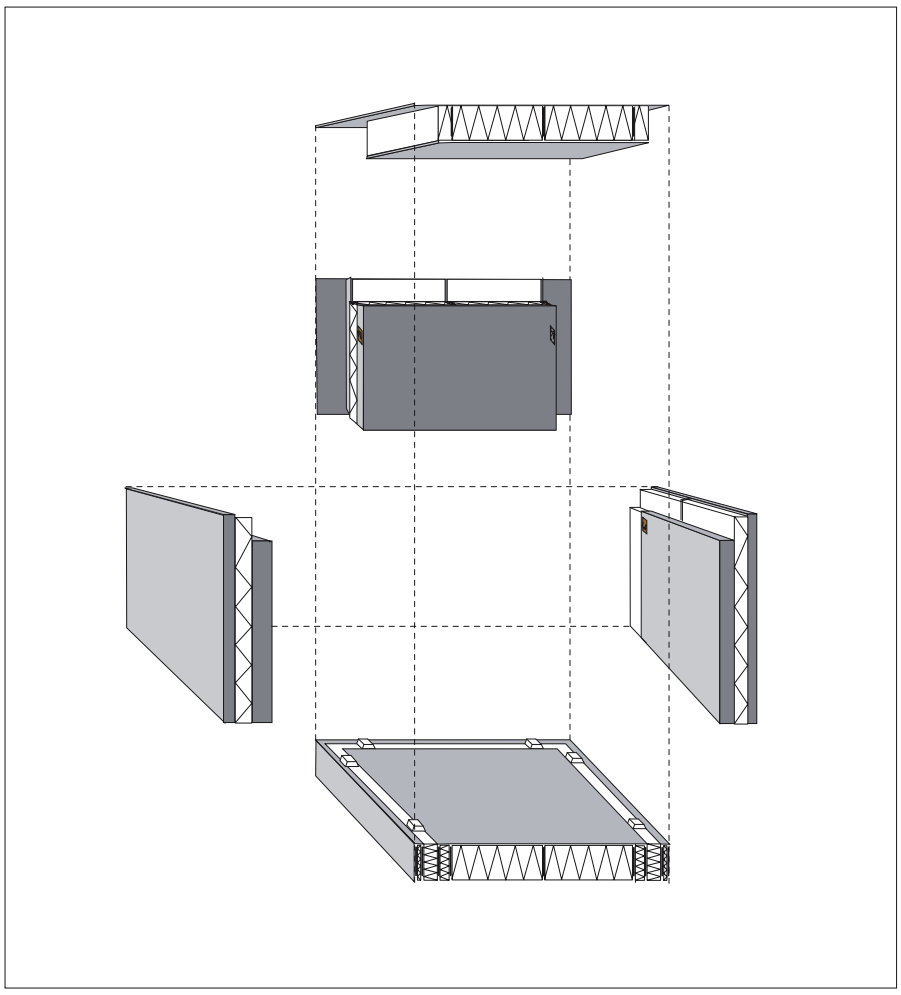
In picking up the threat from the initial field studies and the investigation into lean production theory I continued working conceptually on the idea to spatially exploit the module joints between the volume elements as furnishing and space articulating mechanism in themselves, as implied in the attempted practical positioning of *interiority* in Chapter 6 of Volume 1, see page 41. The summer of 2008 however past quickly and without room to develop and test this concept in practice, instead focus in the production was entirely that of gaining control of expenses as the first housing model had proven way over budget in production. Simultaneously the sales department had trouble disposing of the new simpler 'Square House' types also designed by Arkitema. Thus, when I left Denmark in September 2008 to spend the rest of the year on a research stay at the 'Lehrstuhl für Gebäudelehre und Produktentwicklung' at TU in Munich I went with the interior wish that the situation would stabilize and hereby allow room for later experimentation and implementation of some of the developed prototypes and concepts. Instead something entirely unexpected happened; namely the break out of the 'credit crunch'. From one month to the other sales at both Hjem A/S and Boel Living A/S stopped, challenging the not even year-old factory at Boel Living further. A great deal of the employees were fired and the two sister companies began direct cooperation in order to cut expenses. When seen in addition to the fact that the hitherto production had proved that the degree to which the wood frame construction can be optimized at the factory is limited due to the complexity of layers included with vapour barrier, interior and exterior sheeting, additional paint and façade solutions, the situation was frightening. The construction had too many parts, many of which were in principle 'invisible' in the end product. Especially at Boel Living which was at that time still in the start-up phase and therefore already vulnerable, these findings were potentially fatal; we had not found the key to a profitable construction of the envisioned volume element production. However, even though these findings were clear and radical changes were indeed needed I think that it is only a very few people who have the courage which the general manager of both companies Knud Boel Troelsen showed in this situation as he initiated the development of an entirely new way of constructing the houses.

After a meeting in December 2008 it was decided to initiate development of a lightweight sandwich construction incorporating high strength concrete cover layers suitable for the entire envelope. I was hired to facilitate the development together with our production manager at that time and two production workers who could be in charge of prototyping and a new external engineer Voss Sørensen & Partner ApS. As it stood clear that this development project would become a full time occupation, I made an agreement with the university to take six months leave of absence from the PhD studies and was taken on as a project leader on that particular project at the factory for the first six months of 2009. This was a chance to start over and to utilize our experiences with the wood frame construction, it was a great chance for the factory but also with regards to my research project it was the case that I had been waiting for, the ultimate chance to pursue test and application of the developed interior theory; for integrating home and system. However, we also knew from the beginning that we were working under a time pressure, a strongly limited budget and that we would probably have only one shot to make it work. The basic idea was simple, namely that of developing a single sandwich construction consisting of a light but rigid insulating material covered by thin layers of high strength concrete, applicable for deck, wall and roof elements alike which would not only eliminate many of the excess layers of the original wood frame construction, but also allow for the development of a highly insulated and extremely tight building envelope, where every inch of the construction is insulating except for the thin cover layers made of high strength concrete, see page 51 and 53. The cover layers would provide the necessary stiffness to the construction as a whole, while simultaneously offering a surface quality which could be used directly as it is when, coming out of the mold in both interior and exterior, an idea coming from airplanes, wind turbines and boat hulls and which is pursued by a number of other companies these years.

When initiating the project in January 2009 still aiming to produce single family houses and row houses for the Danish market but also at the potential of arriving at a cost effective system which could be utilized in improving low cost housing in developing countries, we were in need of fast results and hence had to work simultaneously in developing the sandwich construction itself, the production line and the architecture of the intended products so to speak. In comparison with the proceeding process underlying the first housing types and wood frame production at Boel Living which had involved external architects, engineers and considerable funding, our working group for the development project now consisted of only a handful of people. Hence, an integrated process was thus not only a desire as I had found in the theory development but also a plain simple necessity. The specific product intended as the first one to leave the factory was a zero energy single family house. Thus already from the start-up the ambition was not only to develop the proposed new envelope, but also to master all its potentials in the first take. The expected surplus from the effective and energy efficient construction method was intended transformed in the inclusion of solar panels allowing us to offer a completely self-sufficient home to the Danish market at a prize which did not exceed other standard homes. Consequently we were working concurrently on the first experiments with actually fabricating the envisioned sandwich construction, sales, applications for funding, tests and patenting, energy calculations, branding strategies etc. In many ways this, now necessary, but also theoretically desired integrated working constellation proved successful. However, as I will account for below we have also had to face the fact that trees seldom grow to the sky.



Concept diagram for the proposed novel high-strength concrete prefab building system and housing series, spring 2009.



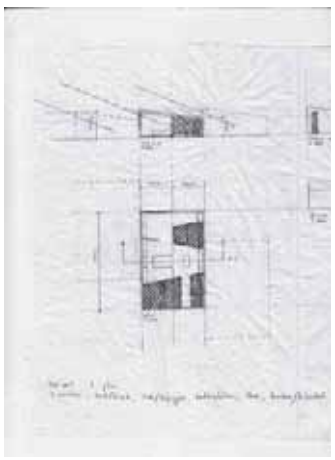
Initial idea for built up and assembly of the novel high-strength concrete system, spring 2009.

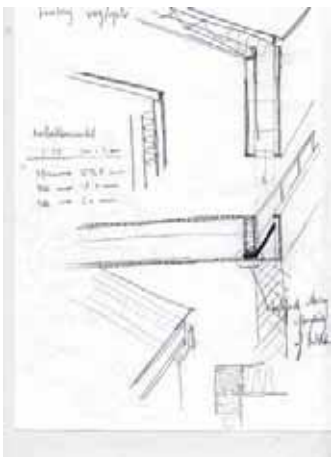
Test of bending strength of the high-strength concrete and EPS sandwich, spring 2009

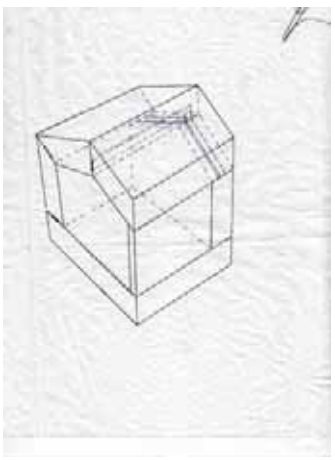
Already when initiating the sketching process dealing with construction and production processes and details as well as actual plan solutions for the first prototype house we simultaneously began our first experiments with actually casting the high-strength concrete sandwich. Our first primary concern was the development of the production principle for actually casting the sandwich element but also that of assuring its strength and fire-resistance. In order to achieve an actual sandwich effect we would have to make sure that loads could be transferred from what would become the exterior cover layer via the insulation and binders to the interior cover layer and vice versa, hence that the sandwich would become able to function as a plate in the horizontal deck and roof elements and as shear walls in the vertical wall elements. This requires a significant bonding of the concrete and the rigid insulation material for which we chose expanded polystyrene (EPS) which is rigid, easy to adjust, cheap and recyclable. There are other more rigid and less temperature sensitive foam materials such as polyisocyanurate (PIR) and polyurethane (PUR) and which would therefore be desirable with regards to achieving the necessary fire resistance, these materials however have less convincing environmental profiles and are a lot costlier than EPS. From the beginning we were entirely dependent on arriving at a cost-effective solution, and thus started out our casting experiments in a simple wooden mold that we could easily adjust in developing the production principle before scaling up the set up. Hence in comparison with the process that we had just witnessed with the wood-frame construction and the production of the first houses at the factory everything was turned upside down, rather than starting out with the full equipment we started out with a tiny 300 liter concrete mixer and a wheelbarrow so to speak. Whereas at a general level these extremely tight conditions were on paper way too tight in comparison with the ambitions of the project, it is my observation that far along the way, these same conditions helped provoke an extremely creative mood and will in the project group. The process and number of experiments, tests, and prototypes made is too lengthy to go through in all details. However I have included a number of sketches and photos on the pages below illustrating some of the steps taken which I hope will supplements this written summary of the course of events in which I present only a few examples.

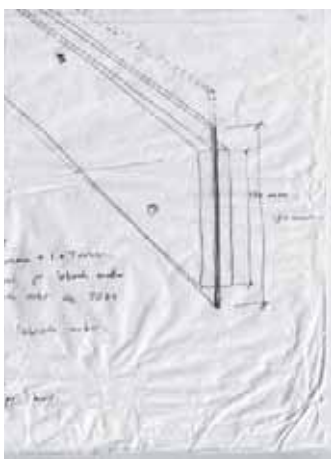
As we were constantly aiming at achieving the lightest and most cost effective built up of the envelope we were necessarily prepared to test new material combinations. The key issue with regards the economy of the envisioned sandwich proved to be the concrete itself. The dense structure of high strength concrete, which is otherwise used mainly for off shore constructions and only for rather exclusive details within architecture, contains only very little water making it tight and fine and enables the achievement of a silky tactile surface which completely mirrors the casting mold. Because of its tightness it can in principle function as both interior and exterior finish without further treatment. As a consequence of these improved material properties this type of concrete is necessarily a lot costlier than standard concrete. Its strength and tightness however makes it possible to reduce the thickness and hereby material use achieving very slender constructions allowing for a simultaneous increase of insulation material. From the initial experiments our focus was consequently to reduce the thickness of the concrete cover layers as much as possible preferably down to only 12 mm. Whereas this special type of concrete has a compressive strength of up to 400 MPa, it still needs reinforcement to obtain significant tensile strength. The usual reinforcement used for concrete is steel, which however proved problematic for our sandwich construction, firstly because it is heavy, secondly because it requires considerable thicknesses in concrete coverage to prevent corrosion. Both for reinforcement of the cover layers of the sandwich and for transferring loads between the two cover layers as binders, our first experiments proved that steel was likewise difficult to handle just as it is not easily adjusted. Consequently, we came up with the idea to start utilizing finely meshed glass fiber fabric as tensile reinforcement instead, which does not only even out the loads compared to the steel reinforcement but has also extremely easy to handle as it can be simply cut into the desired size. By hand it can actually be done with a hobby knife. For the necessary binders between the top and bottom cover layer we likewise found an alternative solution in a simple perlite based glass fiber reinforced plate usually used as exterior wind board in our wood frame construction. This plate not only proved efficient in obtaining the shear forces due to its tight bonding with the concrete but likewise enabled a reduction of weight and elimination of thermal bridges. From simple experiments done in cooperation we thus gradually arrived at a solution for the built up of the sandwich which could obtain the required loads and we were gradually arriving at a more and more cost efficient system for how to actually produce the sandwich construction. The fruitful part of this way of working, in which we were actually trying out ideas architect, engineer, production manager and workers together, enabling immediate feedback of and hands on experience of every slight change made, it became clear that everybody gained ownership in the development. In relation to the theory development I likewise experienced that the effort shared in safety shoes, overalls and helmet was rewarded in a more direct dialogue and interest among all parties in discussing the detailed qualities of the houses we were eventually going to built, hence I experienced that there is a potential to succeed in positioning the need for *interiority* as the centre of practical development.

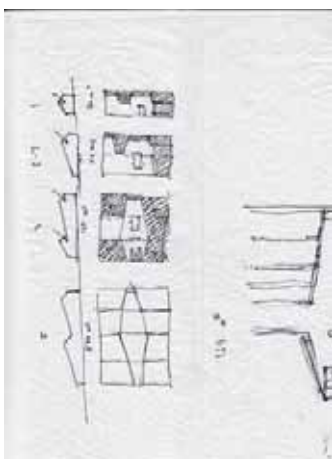
As mentioned we had arrived at a promising solution for the buildup of planar sandwich elements which had passed both compression and bending tests, see page 53 and 56. The elements tested were built up of 300 mm thick and 600 mm wide EPS blocks spanning the entire length of 4500 mm of the tested element and incorporated the mentioned glass fiber mesh and only 12mm high strength concrete cover layers. Spanning 4500 mm it withstood double the calculated dimensioning load in bending with a deflection of only

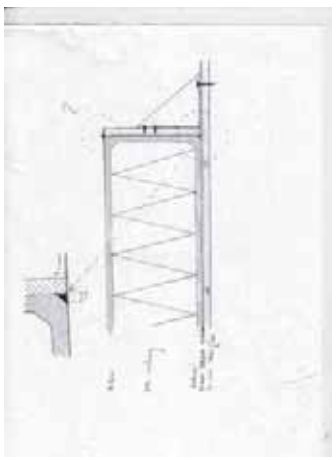




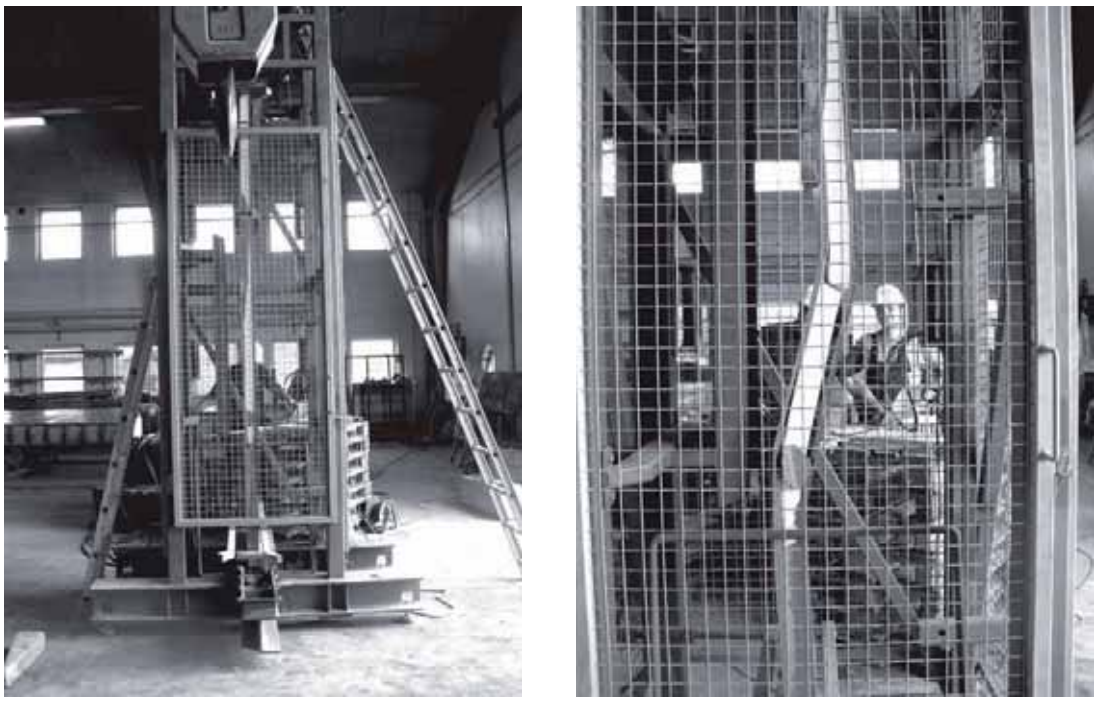




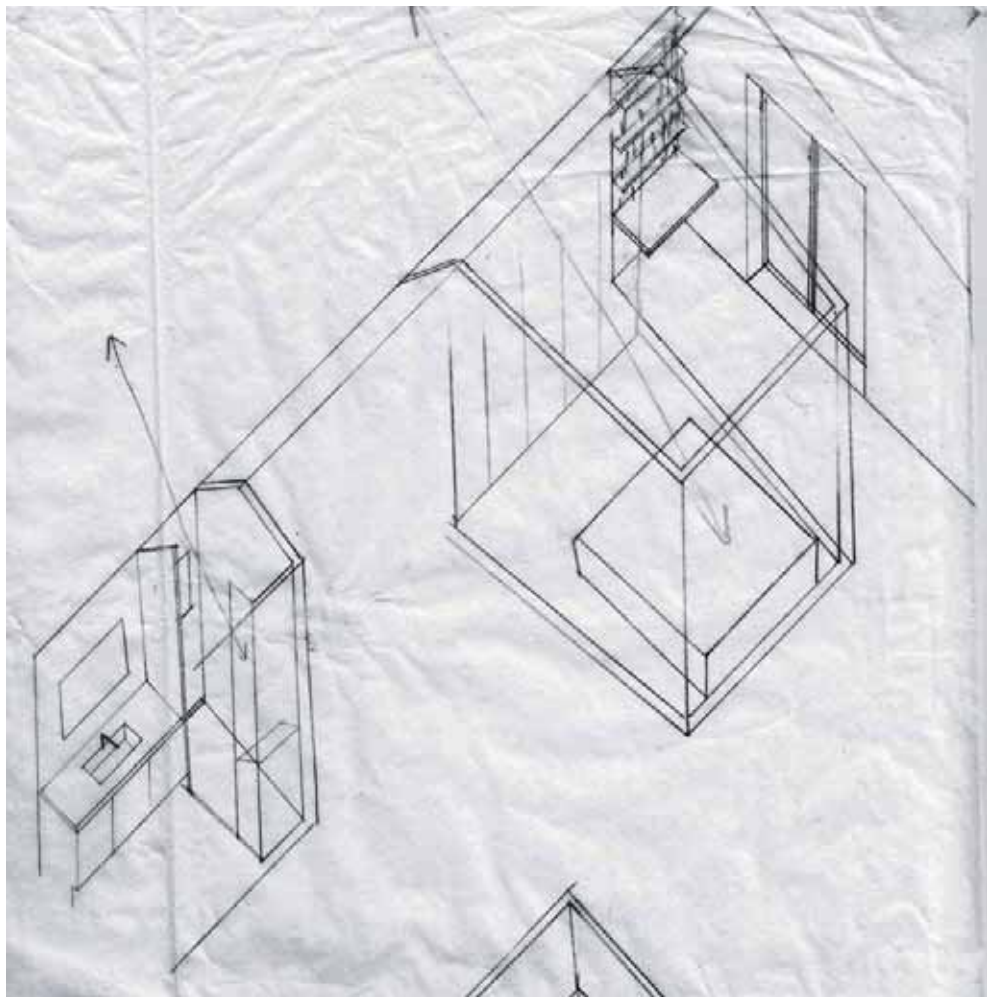




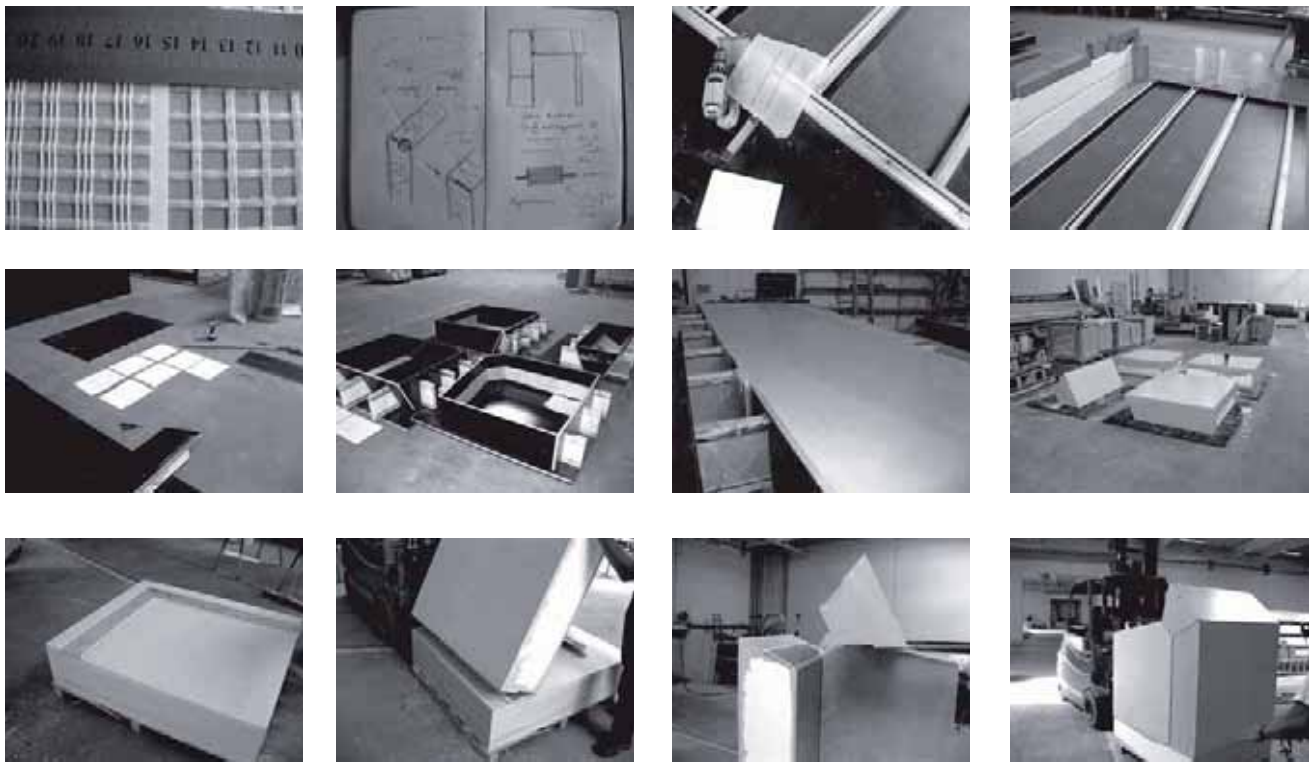
Sketches of plan solutions, assembly systems, casting etc. from the development of the sandwich construction, spring/summer 2009



Vertical testing of wall element of the sandwich construction, spring 2009.



Sketches of interior for the intended prototype house incorporating the sandwich construction, spring/summer 2009



Casting of prototype of the developed sandich construction and assembly system, summer 2009.

Casting of comple 4500 x 12500 mm deck-element summer 2009

a few millimeters and three times the dimensioning load in compression! We had also obtained a principle for how to build up an actual production line and were successful in achieving a convincing surface finish even for large formats, not to mention the fact that the expenses were sufficiently low. In the early summer of 2008 we had likewise developed the principle for joining the elements via a simple groove and recess principle which is identical for all joints in assembly of planar elements into complete volume elements and we consequently filed a patent application for both the sandwich itself and the complete envelope system, while continuing the work towards actual implementation, see page 75 (Troelsen, Frier & Troelsen 2009). As it can be seen from the photos on page 58 and 61 the initial findings from the field studies concerning the wood frame construction related to joints and tolerances proved applicable in the development of the sandwich elements and the building system combining it into a complete envelope. For all project parties involves it was stimulating to experience that we were able to draw these parallels and to use them to move forward. Also the fact that we were all participating in the actual experiments at the factory discussing everything from the fluidity of the concrete to assembly and transportation blue and white collars together proved crucial in gaining an overview of the process.

Applied as deck elements in one storey single family housing the sandwich construction was ready for implementation, whereas for wall and roof elements there were still fire-issues to be overcome. Consequently the deck elements were set in production and implemented in the production at Hjem A/S providing a more efficient deck solution for the wood frame houses produced there. In comparison to earlier wood and steel frame solutions the sandwich allowed for a reduction of the foundation work on site, providing a tight and completely closed plate which can be installed directly on simple linear foundations, see page 51. With very simple means we had succeeded in setting up a production line for producing these decks in dimensions of up to 4500 x 12500 mm hence making up the 'bottom' of a complete volume element, see page 59. However, we still had not arrived at an actual architectural exploitation of the potentials of the sandwich, its surface qualities, appllictation in furnishing details etc.; implemented as decks for the wood frame houses it was not even visible. Whereas we were beginning to get a grip of the construct one could however rightfully raise the concern that we were simultaneously getting lost in construct. Was I, just as I had criticized Wachsmann attaining the role of a system engineer rather than an architect? The second and third paper which I have chosen to include here discusses precisely that; the first one from a practice oriented perspective, the next one consequently pursuing a linkage back to the practical findings in the theory development concerning *interiority*.

Prototype of the developed and patented sandwich construction and assembly system.

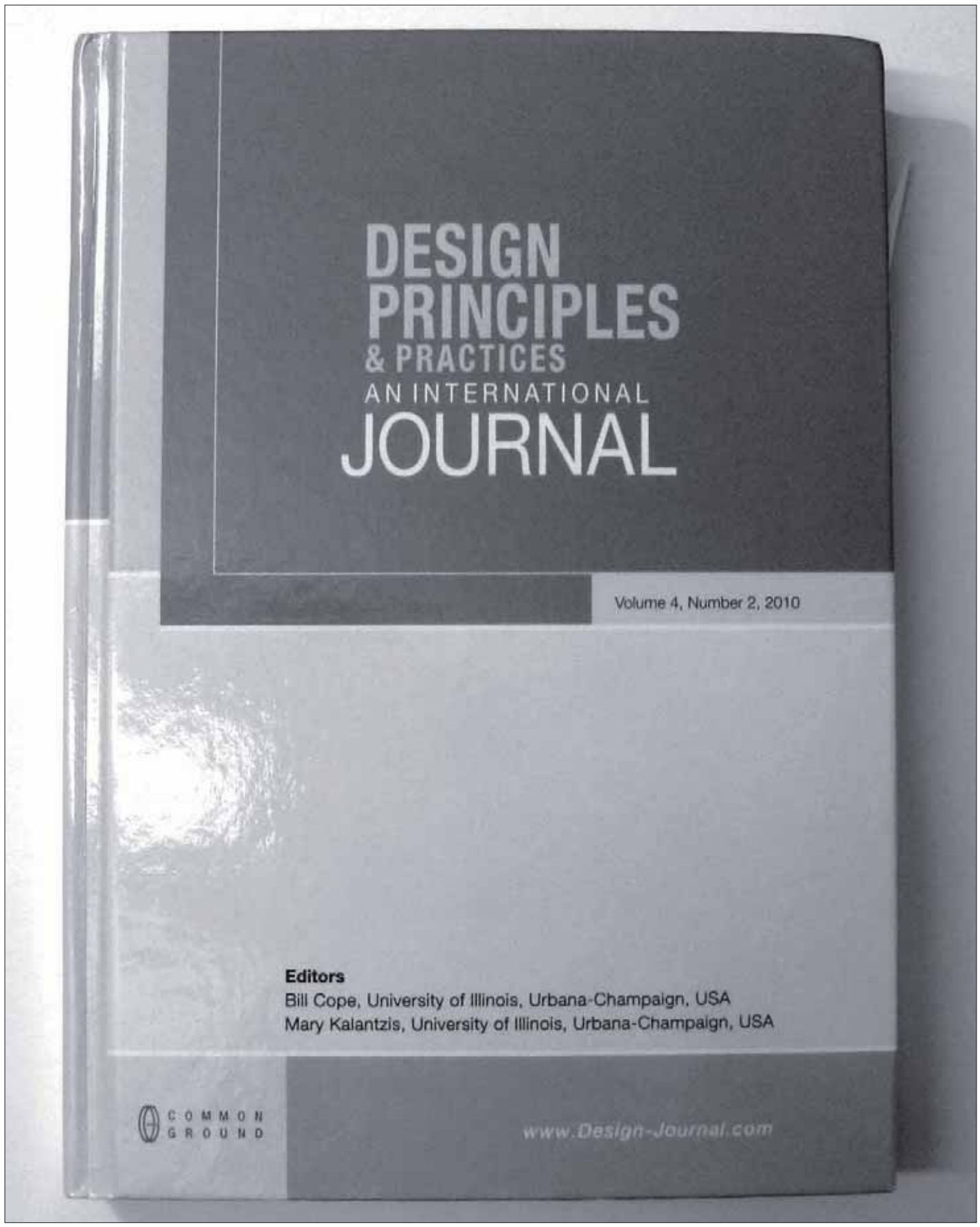
Paper 2:

'PREFAB-INTERIORITY: DESIGN PRINCIPLES FOR A SENSUOUS PREFAB PRACTICE'

Published in 'Design Principles and Practices: an International Journal'
Volume 4, Number 2 of 2010

Published in the spring of 2010 the second of the selected papers at once represents a belief in the results which we had at that time achieved at the factory and the fact that with regards to the PhD research the first results in the pursued linking of theory and practice were positive, however, also a nascent insecurity as to how we would manage to continue. At a general level we had found application of the discoveries made in the first field studies and the early wooden experiments with solving the joint and tolerance problems which I had found lie at the core of prefab production. This geometrical understanding of the house as stemming from an assembly of parts inspired by Blaser's furniture experiments, rather than from a construction section as do a traditional house, showed promising results at the production line in the factory. However, as stated above the architectural exploitation of our inventions with the sandwich elements itself and the building system was still only conceptual. Personally I was beginning to experience, on my own body so to speak, why the question of the eventual domestic architectural quality is often pushed in the background when faced with the economical and structural realm of practice. And in relation to the application of the developed interior domestic architectural theory, that whereas an actual spatial exploitation of the economical and structural elements of construction is a necessary goal and theoretically possible, it's practical revelation entails a complex unity of opposing forces. It would be obvious to conclude that eventually the sensuous detailing of unique villas such as those of Charles Rennie Mackintosh, Frank Lloyd Wright, Adolf Loos, Le Corbusier and Rudolph Michael Schindler analyzed in Chapter 5 of Volume 1 cost: To state that quality costs and to leave the question of the quality of the ordinary dwelling and the prefabricated house to the occasional user survey.

However, on the other hand the process had also documented my observation that in this process the only possible advocate of the user's needs is eventually the architect. Especially in prefabrication which, in most cases, involves the development of a context less house envisioned for a 'standard' site and user, as stated introductorily, the user is not directly represented in the development of his or her house. At times of economical prosperity housing manufacturers may stretch themselves as far as to invite futurologists such as Jesper Bo Jensen and Marianne Levinsen of fremforsk.dk to account for the latest trends in user needs or to have a researcher do an actual user survey, in times of recession as I observed, not even that (Jensen, Levinsen 2009). However, whereas such accounts and surveys can be useful at a general level, it is important to keep in mind that the results hereof cannot be translated 'one to one' architecturally as stated also by Vogler (Vogler 2005 p. 131). Eventually we are as architects responsible for positioning and architecturally visualizing these needs; for translating them into experiences of *interiority*. Of course the recession which hit in the fall of 2008 played a significant part in the course of events at the factory. However, it is my observation that the architectural conditions which I experienced there are by no means unusual. Actually Boel Living is one of only a few on the market who have been willing to deal with architecture and architects at all. If we as architects want a say in the development of the ordinary dwelling these are the conditions; the road to increased domestic architectural quality is preconditioned by a will to get our hands dirty so to speak trying to understand the production system, maybe even to take on a leading role in this matter. In the intense development process surrounding the development of the novel sandwich construction at the factory I assumed the role of inventor, construction- and production engineer, which was indeed fruitful for the cooperation. However, in the clarity of the rear mirror it is likewise a fact that my initial architectural goals was to some extent pushed into the background in this endeavor to understand and act within these conditions. The third paper which is included below discusses this need for the architect to on the one hand understand the boundaries and conditions of the production system while simultaneously exploiting these conditions architecturally.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Prefab-Interiority: Design Principles for a Sensuous Prefab Practice

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Abstract: Despite the global, and still increasing, need for cost effective homes, the envisioned potential of technically utilizing prefab processes as a means of meeting this need has remained a challenging matter. Especially sensuous spatial qualities are often lost within the technical, economic, and practical realm of prefabrication, leaving the produced houses as monotonous box-like constructions rather than inhabitable homes. But what are the sensuous qualities actually spatially defining a home, and how to formulate design principles for developing and revealing these qualities within prefab practice? It is our hypothesis that the inhabitant's experience of home is dependent on sensuous impressions of interiority, spatial detailing at the threshold of furniture, such as an embracing window seat. However, within the practical realm of prefabrication, the revelation of such sensuous spatial qualities is significantly dependent on our constructive ability to economically and production-technically join building elements. Consequently this paper explores the potential for developing interiority as a theory and design principle for transforming constructive challenges within prefab practice into sensuous spatial qualities in the future prefab home. In this matter the paper presents a specific case study, a practice-oriented research project concerning the development of a novel prefab building system and housing series, done in cooperation with the Danish prefab housing manufacturer Boel Living A/S. As a research result the paper suggests a positioning of interiority as a theory and design principle for developing a sensuous prefab practice.

Keywords: Prefabricated Houses, Interiority, Sensuous Spatial qualities, Construction Technique, Joints

Introduction

Prefabrication

FOR OVER A century prefabrication has been envisioned as a means of lowering costs and improving quality through fast, precise and effective production. Especially within the context of domestic architecture the idea, or as formulated by Gilbert Herbert, *'the dream'* of the factory made house, has been inextricably linked with the intention to meet the still increasing and global need for architectural improvement and cost-efficiency of the ordinary house (Herbert 1984). This task of establishing *'the mass-production spirit'*, as proposed in an article by Le Corbusier as early as in 1919 and republished later in 1923 in his 'Towards a New Architecture', sprang from the challenges and opportunities posed by the industry and the intention to utilize technology in spatially establishing *'the elements of the house on a mass production basis'* (Corbusier 2000 p.6). However, whereas the 'dream of the factory-made house' spread, as described by Gilbert Herbert and later by

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Colin Davies among others, the task of formulating actual design principles capable of fostering a practical revelation of this dream has proved to be a challenging matter (Herbert 1984, Davies 2005). As described in Herbert's analysis of the works of Walter Gropius and Konrad Wachsmann, and in Arieff & Buckhart's more recent prefab study, the necessary sensuous spatial qualities of *home* are often lost within the technicality of construction as a system (Herbert 1984, Arieff, Burkhart 2003). Wachsmann's early search for the 'perfect joint' is just one example of such technical ventures, which as many others, never led to any spatial results. Actually the transformation of traditional onsite 'bit by bit' construction into high precision factory assembly in itself has often caused joint and tolerance challenges making prefabrication as expensive as traditional construction as studied in (Frier, Kirkegaard & Fisker 2008 p.533-540). As a consequence the houses which have actually reached production are often experienced as monotonous box-like constructions rather than sensuous inhabitable *homes*, often produced completely without the involvement of architects (Arieff, Burkhart 2003 p.9-10). Thus, when held together with Corbusier's initial vision, the challenge of the prefabricated house seems to be both constructive and spatial. To Corbusier, the revelation of the *'mass-production spirit'* was not solely a technical and constructive practical issue but also a sensuous spatial matter. In stating that the mass produced house should be beautiful not only in the *'way that the working tools and instruments which accompany our existence are beautiful'* but also *'with all the animation that the artist's sensibility can add to severe and pure functioning elements'* this position is evident (Corbusier 2000 p.7). Herein Corbusier aspired to the less tangible but, it is our claim, vital sensuous spatial qualities of *home*. However, whereas this envisioned sensitivity can be experienced in the intimacy of the interior detailing of for example the bath in Corbusier's 'Villa Savoye' or the built-in seats and bookshelves of Frank Lloyd Wright's 'Fallingwater' these works were, as many other works of the Modernist pioneers, out of constructive reach of prefab practice and hereby also out of economic reach of the general public. Thus, at a general level, the success of future prefab endeavors seems to be dependent on our ability as architects to engage with the practical and economical realm of prefabrication attempting to transform the before mentioned constructive challenges into sensuous spatial qualities, integrating space and construction. *But what are the sensuous qualities spatially defining a home and how to formulate design principles for developing and revealing these qualities within prefab practice?*

It is our hypothesis that the inhabitant's experience of *home* is dependent spatially on sensuous spatial impressions of *interiority,* detailing at the threshold of furniture. We herein imply that sensuous spatial detailing such as a built-in mezzanine or a sky lit shower are crucial elements in our recognition of a particular space as *home*. The bath in Corbusier's 'Villa Savoye' or the built-in seats in Wright's 'Fallingwater' are examples of this interior quality of *home*, however, representing a level of detailing which is, as described above, seldom achieved in the prefabricated house. The works are both unique examples expressing the architects' spatial and aesthetic visions but with no direct relation to prefabrication. However, it is our belief that they are significant examples in developing a general understanding of, *'the elements of the house'* as described by Corbusier, unfolding points of *interiority* in which the inhabitant actually interacts with the *home*; sitting, lying, bathing, cooking, resting. Following this line of thought, *interiority* as a spatial sensuous encounter, is therefore also crucial as a point of departure in the development of design principles for a sensuous future prefab practice. Consequently it is the goal of this paper to explore the potential for

developing *interiority* as a theory and design principle for transforming constructive challenges within prefab practice into sensuous spatial qualities in the future prefab *home*.

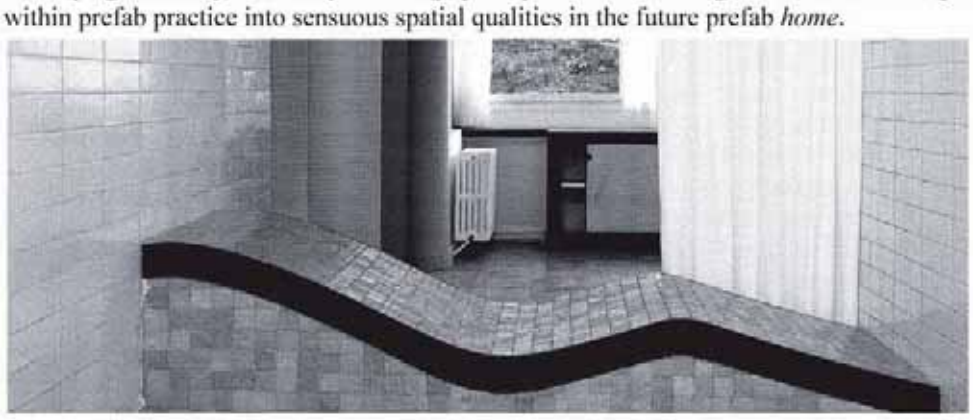

Figure 1: Bath in 'Villa Savoye' 1928 (Photo by Ralph Liebermann, Published in (Marcus 2000))

Interiority

When utilizing the term *interiority* in an initial attempt to approach a spatial definition of *home*, we herein intuitively suggest a necessary venture into a boundary field interrelating that of architecture and furniture. This suggestion of an architectural approaching of the human body akin to that of furniture is rooted in interior architecture as a discipline. With its origin in the Bourgeois interior of the nineteenth century as studied by Charles Rice, the interior has emerged not only as a practical discipline but also as a research field (Rice 2007). As described by Charles Rice, the term *interiority* initially described inner subjectivity; but, later it became related also to the interior of a physical space, herein the sensuous aspects of furnishing, as studied by Mario Praz, Anne Massey and John Pile among others (Rice 2007, Praz 1964, Massey 2001, Pile 2009). Besides ongoing publication of now three refereed journals counting *Journal of Interior Design* established in 1993, the *IDEA Journal* published since 2001, and the brand new *Interiors: Design, Architecture and Culture* a number of researchers have published individual monographs as well as edited anthologies on the sensuous, spatial, historical and cultural aspects of the interior and *interiority* as a field. Charles Rice's 'The Emergence of the Interior', John Kurtich and Garret Eakin's 'Interior Architecture' and Mark Taylor and Julieanna Preston's 'INTIMUS: Interior Design Theory Reader' are examples hereof (Rice 2007, Kurtich, Eakin 1993, Taylor, Preston 2006). However, when related to the above outline of the challenges of prefabrication, the revelation of the sensuous potential of the interior becomes significantly dependent on our constructive ability to economically and production-technically join building elements. Thus, we are here specifically pursuing a linking of *interiority*, as a sensuous and spatial theoretical approach to the *home* with a practical and constructive understanding of the technical conditions characterizing prefab practice; an integration of space and construction.

Methodologically this is pursued by relating a deductive study of *interiority* as a constructive theory and design principle with an actual practical case study; a practice-oriented research project concerning the development of a novel prefab building system and housing series

done in cooperation with the Danish prefab housing manufacturer Boel Living A/S. In the theory development we turn to architecture's technical basis and a comparative study of Gottfried Semper's theories on the origins of construction with Werner Blaser's more recent studies of the physical interrelation of space and construction manifest in the joint (Semper 1989, Blaser, von Büren 1992). A thorough version of this study, which is currently being reviewed for publication in connection with the international 'Structures and Architecture' conference in Guimarães, Portugal, July 2010, is summarized in the section below forming the theoretical framework for discussing the described practical case study presented and evaluated in the final section of this paper. Specifically the case study concerns the development of a light sandwich construction system in high-strength concrete and proposals for the development of the spatial potentials of this particular construction in a novel housing series. Held together these studies will be used as a basis for discussing the establishing of *interiority* as a theory and design principle for developing a sensuous prefab practice.

Interiority as a Theory and Design Principle

Space & Construction

In his studies of the origins of construction leading to the formulation of his 'Four Elements of Architecture'; the *'hearth, roof, enclosure and mound'*, Semper especially noticed the conditions of the enclosure as being related to the ancient technique of weaving (Semper 1989, Semper 2004). In stating that the carpet *'in its capacity as a wall'* signifies the evolution of certain architectural forms, he concluded that the technique of weaving is the source of the oldest forms of ornamentation, herein describing construction as a sensuous spatial as well as a technical practical matter, defining the enclosure dually as the space creating softness of the textile and the constructive hardness of the wall (Semper 1989 p. 104). It is our claim that this duality can be rediscovered in the sensitive interrelation of architecture and furniture in the works of architects such as Corbusier and Wright. In both cases their works often consist of several interrelating, but precisely orchestrated layers. One example is Wright's furnishing interior constructions creating spaces in which to sit, read, eat etc. These are seldom direct structural elements, but are significant in adapting the hard outer structure of the wall or load bearing column to the softness of the human body. However, when considering prefabrication and the level of system and economy required here, the question is if this necessary sensuous and furnishing detailing can be related directly to the structural means of construction; to the actual jointing of constructive elements. Thus, in the following we will be addressing the technical challenge of jointing structural elements through an occupation with the works of Werner Blaser.

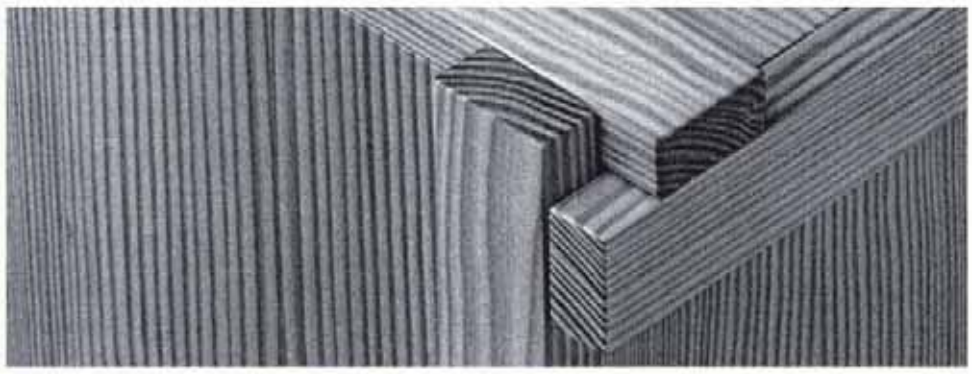

Figure 2: Wooden Furniture Joint by Werner Blaser (Photo by Werner Blaser, Published in (Blaser, von Büren 1992))

Through his works and writings Blaser zooms in on the interrelation of architecture and furniture addressing a direct aesthetic and technical relation between the two (Blaser 1985 p.9). Due to his particular focus on the history of the joint, his work has been precisely described as a *'system'* of furniture making by Katharina Steib and Arthur Rüegg (Blaser, von Büren 1992). By using his skills as a designer and as a photographer he studies the joint and its relation to the chair in furniture design and to construction and the articulation of space within architecture, unfolding a library of geometric solutions to the basic problem of the joint. His illustrations of particular joints; strut connected to strut, strut to plane, plane to plane etc. can be considered prototypes and architectural exercises exemplifying necessary architectural techniques, especially with regards to prefabrication. Thus, to Blaser the key to architectural aesthetics lies in the simplicity of the joint and the architect's ability to relate the aesthetic solution of the joint to the means of manufacture, which make his studies of particular interest to our endeavor here of formulating design principles which can be actualized within the realm of prefab practice (Blaser, von Büren 1992).

As argued above prefabrication seems to be paradoxically dependent on our ability to look at the *home* as a system, thus integrating space and construction. In relation hereto Blaser's occupation with the joint may be regarded insufficient as a *home* in itself, which Wachsmann's endless search for the 'perfect joint' is an example of, thoroughly described in (Herbert 1984). However, Blaser's studies pinpoint the necessity of the architect's structural and geometrical skills; a knowledge which, especially within the context of prefabrication is an economical and constructive means, preconditioning spatial exploitations. When combining the specific understanding of the *interiority* of construction developed by Blaser with the inherent spatial *interiority* of the enclosure described by Semper, a theoretical potential for developing a constructive relation between the necessary sensuous spatial quality of *home* and prefabrication as a constructive, economical and production-technical system opens up. In summarizing the preceding studies in relation to our initial hypothesis, construction can ideally be understood as space and the joint as a sensuous spatial quality. Following this line of thought one could have imagined Wachsmann's 'perfect joint', described earlier, developed as a spatial furnishing detail in relation to the development of both plan and section within the prefabricated house, maybe even fitted with cushions or textiles, rather than solely a technical precaution. With this observation as a point of departure we can begin to consider

interiority not solely as an intuitive expression used in an initial attempt to spatially define the *home* but also as an actual theory and design principle for practically transforming the constructive prefab challenges, described by Gilbert Herbert in particular, into sensuous spatial qualities (Herbert 1984). The question is, however, to which extent the sensuous need for furnishing detailing of space can be integrated with the constructive need for a systematic practical solution to the joint? In order to discuss this matter in relation to the actual practical realm of prefab construction, as suggested earlier, the following section introduces a specific prefab case study. The description of the case study relies on field studies which have been done at Boel Living as an integral part of our specific research and as a partaking in the actual product development at the factory.

Case Study

Prefab Practice

In this final section of the paper, application as well as discussion of the proposed formulation of *interiority* as a theory and design principle within the practical realm of prefabrication is pursued. However, before moving into the particularities of the case study, a brief introduction to Boel Living and the initial field studies which have led to the idea of developing an entirely new construction system is necessary.

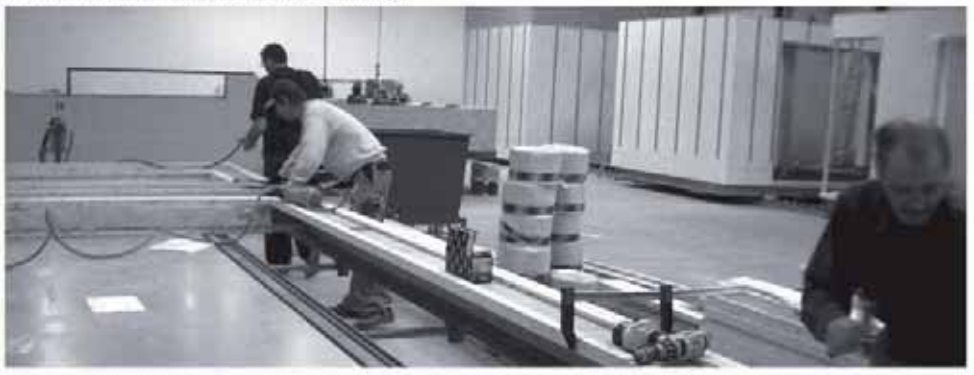

Figure 3: Traditional Wood-frame Construction in Production at Boel Living

Boel Living is an innovative Danish housing manufacturer producing row- and single family houses from complete factory fitted volume elements ready for truck transportation and on-site assembly. Until recently the factory has exclusively been using a simple wood frame construction as the basic principle for wall, floor and ceiling elements. The wood frame is a simple system and the construction of the frames can be highly automated, however, in the production at Boel Living it has caused complications in the assembly process. With necessary interior cladding, vapor barrier and exterior weather proofing, the construction becomes complicated consisting of a number of layers, bits and bolts which require a high level of precision in the production process, representing detailing and man hours which are not revealed in the experience of the final product. Likewise the wood frame elements have proved difficult to handle in the assembly and jointing process due to lack of constructive steering mechanisms which can ensure a fast, precise and tight assembly. In addition the

task of using wood for the deck element requires subsequent tightening and foundation work on site. Thus, paralleling the findings of Herbert's historical prefab studies, our field studies have showed that, as a point of departure, the traditional means of construction herein drawings such as plans and sections are insufficient. Rather, focus needs to be on the construction of each element, a wall for example, and the geometrical assembly of that element to the subsequent floor, ceiling and wall elements. Consequently, it is our general observation, that prefabrication is highly dependent on the ability to develop a simple geometrical assembly principle, an approach which could be inspired by Blaser's studies.

As an effect of these challenges of the wood-frame construction, the houses built at the factory, except being good overall solutions, do not contain a significantly improved level of detailing and spatial quality when compared with traditional construction and cost in general. Rather, attempts to visually 'erase' for example the challenging module joints between the prefabricated 'boxes' with paint and plaster in pursuing the visual appearance of traditional on-site construction, have resulted in increased costs but with no spatial reward. Consequently we began to question the suitability of the wood frame construction, which is fundamentally a traditional construction technique developed for on-site construction and not fully exploiting the factory potential either spatially nor constructively. Thus, the motivation for initiating the development of a novel construction system and housing series has been to develop a system 'born' within the factory, a system where the many layers of the wood frame construction can be reduced in a tight and easily assembled and installed building envelope. These criteria led to the development of a simple cast lightweight sandwich element with thin high-strength concrete face sheets and an insulating EPS core material, an element suitable for wall, floor and ceiling elements alike, constituting an entire building envelope (Troelsen, Frier & Troelsen 2009). At a general level this construction system holds a number of potentials particularly in relation to energy-efficiency and sustainability in general due to its simplicity of production, material use, insulation properties and tightness. However, our focus in the following discussion below is limited in focus to the interrelation of its constructive and sensuous spatial potentials, which are the objective of this particular paper.

A Novel Prefab System and Housing Series

Developing a new building system from A to Z holds a particular potential to not only question the practicality of construction and production flow but also the sensuous and spatial perspectives within this development. At Boel Living this potential for a dual spatial and constructive focus has been pursued by joining management, workers, engineer and architect in the project group already from the first stages of the project. Within this project group it has been intended to establish a forum for discussing and developing spatial ideas in relation to the specific development of the sandwich construction in a direct dialogue between the different project parties. Hence, a forum in which the architectural intention of strengthening the sensuous spatial qualities of the eventual *homes,* could be discussed in relation to the workers' and the engineer's constructive experiences. As a preliminary result of this work the principle for casting and for achieving the necessary strength and stiffness of the planar sandwich element as well as a geometrical solution to the jointing of planar elements into a complete building envelope has been developed.

Figure 4: Prototype Envelope with 12 mm Face Sheets and 300 mm Insulation Core, thus a Highly Insulated but thin and Tight Envelope

Informed by the initial factory field studies, revealing the challenges of the wood-frame construction and by Blaser's prototypical geometric studies, a particular joint principle has been invented incorporating a rail mechanism. This rail functions as a tenon and a geometrical steering mechanism in the assembly process and allows for fixing the elements simply by using an elastic glue on each side of the rail, making the construction tight and distributing the forces, while breaking possible thermal bridges. This envelope and assembly principle is currently undergoing further testing and patenting (Troelsen, Frier & Troelsen 2009). However, as a principle it assures a reduction of raw material usage in a highly insulated and tight but also thin envelope, where an easy and economic on-site installation of the individual prefabricated 'boxes' is ensured by the use of inorganic materials making complex foundation work unnecessary. In itself the concrete face sheets function as interior and exterior surfaces with no further treatment, plaster or paint needed. Rather, there is a potential to treat the surfaces directly in the casting process, as the dense structure of the high-strength concrete precisely mirrors the casting form allowing for multiple tactile and visual surface effects. Thus, at a general level there are obvious constructive, production-technical and economic potentials attributed to the novel building system, potentials which can at first hand be transformed in a decrease of production expenses. However, here we are interested particularly in discussing how these construction technical and economical gains can be transformed and developed in relation to the actual spatial detailing of the houses, improving their sensuous qualities as *homes*.

Discussion

So far a prototype house has been sketched while developing the construction system. Herein the utilization of the construction with regards to the general volume has been discussed including the idea to use the most simple pitched roof construction in order to integrate solar panels at the optimum angle, while achieving a graduation of the ceiling height in the interior, as no subsequent construction is structurally needed. Likewise the simplicity and economy of the construction allows for an increased detailing of plan and section with mezzanines, integrated storage etc. One could also imagine how the decrease of costs on the building envelope itself could be utilized in exterior 'furnishing' details, such as shading, storage,

and terraces. Especially for the context-less prefabricated house, meant to be reproduced in different contexts, these spatial means for establishing an interrelation of interior and exterior are perhaps even more crucial than in the unique works where their necessity is well argued for by architectural theoreticians such as Juhani Pallasmaa and Christian Norberg-Schulz (Pallasmaa 1996, Norberg-Schulz 1985). However, whereas the motivation within prefabrication is the envisioned potential of producing more for less, it seems to have been a persistent challenge for architects and manufacturers to reach this goal. As described in the introduction the end result is often a stripped down construction failing to address the sensuous spatial qualities signifying *home*. With current issues such as the financial crisis this tendency is increased, everything which can be 'cut away' is understandably cut away in order to assure the business. However, with or without financial crisis these are conditions, which it is our task as architects to understand and to learn to act within. Thus, in continuation of the theoretical study of the works of Semper and Blaser, it is our observation that the greatest challenge within prefabrication is how to integrate the sensuality of the furnishing detail directly within the constructive logic of the joint. When following this line of thought one could critically say that so far our achievements with the novel building system have been limited to the general economy and logic of the envelope; that we are ourselves at the pitfall of getting lost in construction in a Wachsmann'ian search for the *'perfect joint'*. Thus, the question in relation to our formulated hypothesis is how we can progress from this general optimization of the construction and economy of the building envelope to an actual activation of the constructive joint as a sensuous spatial element. This is a challenge which will necessarily require extensive future studies and experiments to solve. We will use the last section of this chapter to discuss directions for these future studies.

With regards to volume-element construction one of the greatest challenges and hereby also the greatest potentials for improvement is the module-joint. These joints are a key issue, as here the prefabricated 'boxes' of a relatively high precision level are to be joint together quickly and with the utilization of a crane on-site causing a number of tolerance and tightening challenges. Rather than attempting to avoid tolerances by forcing an improvement of precision, the production workers at Boel Living have expressed a need to pursue the development of a joint-principle which can adopt the necessary tolerances, something which becomes clear when observing or better yet, trying out these processes ourselves; managers, architects, engineers and workers alike. At Boel Living these joint workshops have proved that such bridging of professional boundaries can be a fruitful means of creating dialogue and development among project parties. A development which has among other things led to the idea of developing a 'connector', as a kind of intermediate mechanism capable of adopting tolerances and assuring a tight module joint.

Figure 5: The 'Connector' as an Intermediate Furnishing Space-Creating Joint Mechanism

This idea has still only reached a conceptual level; however, from a spatial point of view it holds potentials for future development. One could imagine the 'connector' as an element also affecting the interior as a sensuous spatial furnishing element, an element which could also act as a zone for running installations and storage units doubling as walls, thus virtually organizing the prefabricated house in plan and section. Hereby an actual spatial and sensuous development of the joint is suggested, rather than attempting to erase it in order to make the prefabricated house 'appear' like a traditional on-site construction. Thus, as a concept the sketched 'connector' addresses the interior of the monotonous square boxes dividing and differentiating them as a spatial furnishing element. The utilization of novel CAD/CAM technologies could be imagined integrated here as a future means for refining and developing this concept further, as at the scale of furniture rapid prototyping of complex forms may be economically feasible. In total the development of the proposed 'connector' forms an exciting challenge for the future, which we are eager to pursue.

Conclusions

The goal of this paper has been to examine whether *interiority* can be developed as a theory and design principle for transforming constructive challenges into sensuous spatial qualities within the practical realm of prefabrication. Through a deductive theoretical study of the theories and works of Semper and Blaser we have progressed from an initial intuitive sensuous and spatial occupation with interiority to an actual constructive and technical establishing of *interiority* as a theory and actual practical design principle. In the research at Boel Living this principle of transforming the joints, the problem areas of prefabrication, into sensuous furnishing elements has proved to be a potential new principle for spatially organizing the prefabricated house, improving its sensuous qualities of *home* via the sketched 'connector'. However, the studies have also proved that the question of economically and production-technically integrating space and construction is never immediate. Rather it may still be considered utopian and 'dreamlike' when held together with the constructive and economical conditions governing prefab practice, as described initially by Gilbert Herbert. The idea of following and deliberately involving ourselves with these conditions as architects is however still, it is our conclusion, a significant task, challenge, and most importantly also a fruitful potential for developing a sensuous prefab practice. A potential in which a readdressing and

visualization of the sensuous spatial qualities of *interiority,* signifying the works of pioneering architects such as Corbusier and Wright, are a necessary point of departure for the extensive but exciting future studies and experiments required.

Acknowledgements

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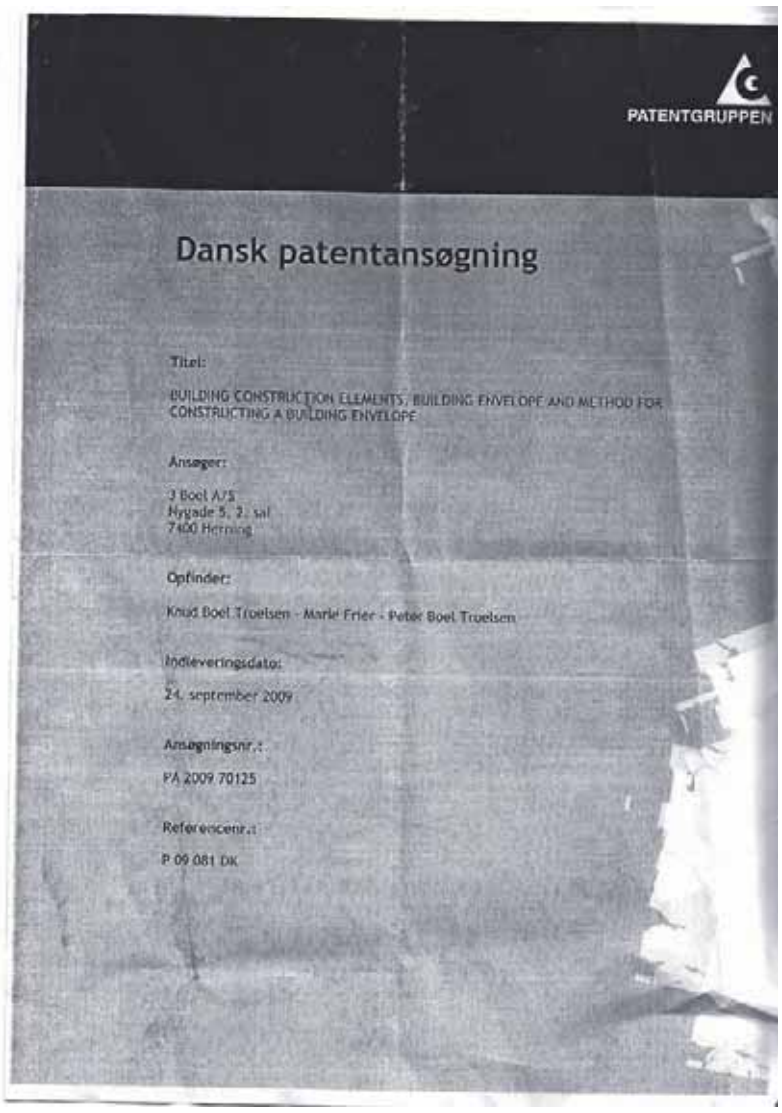


Patentapplication, summer 2009.

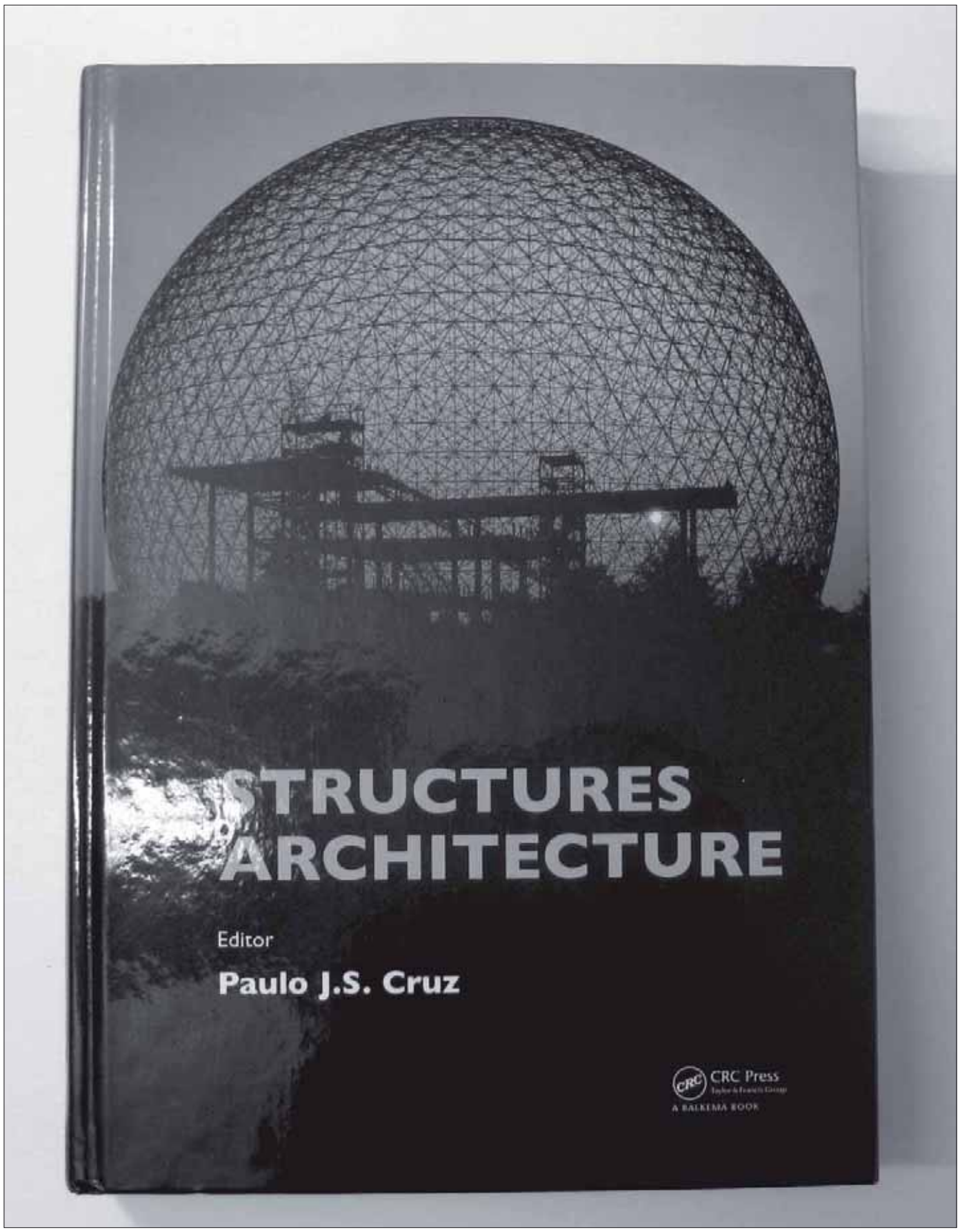
Paper 3:

'TECTONIC THEORY AND PRACTICE: INTERIORITY IN THE FUTURE PREFAB HOME'

Published in the proceedings of the First International Conference on
Structures and Architecture, Guimaräes, Portugal, July 2010

The third of the papers which I have chosen to include here entitled 'Tectonic theory and practice: *interiority* in the future prefab home' was presented and published at the first Structures and Architecture conference in the summer of 2010. Dealing with the relations between architecture and engineering, the conference represented an obvious opportunity to discuss the linkages, which I was pursuing both theoretically in the work on the theory development and practically in the actual field studies at the factory, within a general tectonic framework. Thus, the paper can be seen as an initial attempt at combining literature studies and field studies into a coherent tectonic theory for approaching the particular practice of the prefabricated house. The paper pursues a reintroduction of tectonic theory and practice within the particular context of the prefabricated house, where the immediate sensuous relation between architect, construct and inhabitant characterizing the work of the tekton is in principle distorted, complicated if not even completely dissolved as discussed also in the theory development concerning *interiority*. The means for establishing this reintroduction of tectonic theory and practice within prefab production is the utilization of furniture as an architectural concept, as applied also in the theory development, which at once requires a detailed technical understanding of the production system itself as exemplified in the works of Werner Baser but also an actual spatial exploitation of the economical and structural elements of the construction itself in a sensuous and soft approaching of the human body as spurred in the theories of Gottfried Semper. This utilization of developer serves not solely as a functional and emotional architectural parallel but also as a concept in spurring future constructive developments has become a guiding principle in the theory development itself and in approaching an actual physical visualization of the architectural potential hereof which I still believe in and cannot wait to continue working on.

However, as mentioned above the summer of 2010 was also the point at which we had to face the fact that time was now definitely running out and that the practical revelation of this potential would fail to appear in this instance. Consequently, it was also a time at which to take a look into the rear mirror reflecting upon the course of events rather than clinging to the hope.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Tectonic theory and practice: *interiority* in the future prefab home

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ABSTRACT: Since the first optimistic originally Modernist prefab visions were formulated there has been, and are still, challenges to be overcome in order to fulfill the increasing need for fast, precise and economically produced *homes*. The tectonic need to transform a *home*, into a system of joints and assembly processes, seems a paradoxical challenge which has left prefabricated houses raw constructions rather than inhabitable *homes*.

Based on the hypothesis that *home* is determined spatially via sensuous impressions of *interiority* at the threshold of furniture: The bath in Le Corbusier's 'Villa Savoye' is an example of this sensuous interior transformation of a house into a *home*, a level of detailing which is, however, seldom represented in the prefabricated house. Consequently, this paper investigates whether *interiority* can be developed as a tectonic theory and design principle for uniting *home* and system in the development of novel prefab solutions. This is pursued trough a deductive study comparing Gottfried Semper's theories on the origins of construction with Werner Blaser's technical and practical studies of the joint. In combining Blaser's constructive understanding of the joint with the interior softness defined by Semper as a constructive precondition, a theory for developing a novel tectonic relation between *home* and system opens up. As a research result the paper suggests a practical spatial exploitation of the actual prefab construction, defining *interiority* not solely as a visual occupation with the joint, but as a direct spatial transformation of the joint in a furnishing spatial approaching of the human body.

1 INTRODUCTION

Derived from the greek *tekton* the concept of tectonics describes a particular sensuous *relation* between space and construction, signifying the experienced quality of architecture (Frampton 2001). It is our belief that for the *tekton* (i.e. builder), the experienced architectural quality of his work is a consequence of his inherent empathy. Being at once inhabitant, architect and engineer it is our understanding that his *home* becomes a spatial and constructive expression of his particular way of living. The works of recognized architects such as Le Corbusier and Rudolph M. Schindler are examples of this tectonic interrelation of strong spatial intentions and constructive skills. Despite their different backgrounds and contexts; Corbusier's grand visions for the industrial city in Paris and Schindler's quieter development of individual housing projects in Los Angeles, their works reveal similarities. Based on a lifelong interest in the conditions of *home*, they both reached the conclusion that constructive skills and spatial imagination are dual tasks of the architect (Corbusier 1923, Sheine 1998). For both architects it seems that the experienced architectural quality- and recognition of their works is a result of their empathic ability to imagine themselves the inhabitants of those same works. Prefabrication, however, unfolds increased complexity in the construction process involving a decoupling of this immediate relation between inhabitant, architect and engineer. Despite the optimism of the initial Modernist prefab visions of producing low cost high quality dwellings; the prefabricated house has remained a complex matter (Davies 2005). Over the years architects such as Walther Gropius, Konrad

Wachsmann, Ray and Charles Eames, Buckminster Fuller and many others have pursued developments within prefabrication (Bergdoll (ed.) 2008). However, it seems that they have been persistently challenged by the paradoxical need to transform the sensuous spatial detailing which we believe defines a *home,* into a system defined by general rules of construction. Historically the results have been either spatially interesting prototype homes unsuitable for actual production, such as Fuller's 'Dymaxion' house, or constructive inventions such as Wachsmann's perfect joint not leading to any specific spatial developments (Herbert 1984, Bergdoll (ed.) 2008).

Figure 1. Bath in 'Villa Savoye' 1928 (photo by Ralph Liebermann, published in (Marcus 2000)).

Also Corbusier and Schindler have tried their strength with prefabrication: Corbusier as a direct means in the formulation of his early visions as a Modernist pioneer and Schindler as an attempt to expand his spatial ideas to the lower income classes. Although not realized before the execution of the 'Unité' block in 1952 Corbusier already in his 1914 sketch for the reinforced concrete 'Domino' skeleton imagined prefabrication as a constructive means for developing the spatial potentials of the Modern house (Corbusier 1923). In the Unite block the raw skeleton of the 'Domino' prototype has been transformed into a sensuous interior, with varying ceiling heights, built in furniture, and shading of the natural light. Despite the heavy critique of Corbusier's radical plans, the 'Unité' is an inhabitable block, however, a single example among many uninhabitable blocks built in the 1960's and 70's. Likewise Schindler imagined how prefabrication by means of spray on concrete could help him realize an economic version of his villas (Smith & Darling (ed.) 2001). The 'Schindler Shelters' of 1933 were related sensitively to their exterior surroundings incorporating overhangs and a leveling of the interior spaces. However, in spite of Schindler's particular economic skills the 'Shelters' proved too expensive for actual production like so many other ambitious prefab projects.

Despite the essentially sensuous tectonic visions of significant architects like Corbusier and Schindler it seems that in prefabrication, focus often shifts from spatial detailing to construction. As argued by Gilbert Herbert and Colin Davies among others, especially spatial detailing is often lost within the technicality of the system, leaving the houses raw constructions rather than inhabitable *homes* (Herbert 1984, Davies 2005). Often challenges concerning joints and assembly systems as well as production management and communication have made the prefabricated house even more expensive than traditional construction. Never the less there is still an increasing worldwide need for economic homes as well as a persistent belief in prefabrication as a solution. Latest new of CAD/CAM technologies has breathed new life to these beliefs. However, this development still seems both constructively and spatially immature, and the vision of customized form delineated to expensive prestige projects as discussed in (Hensel et.al. 2009). Consequently there seems to be a need to rethink space and construction simultaneously pursuing a fusion of *home* and system in the development of novel prefab solutions. The question is however, what it is that defines architectural quality and makes a house a *home*?

1.1 *The interiority of space*

It is our hypothesis that a *home* is determined spatially via sensuous impressions of *interiority,* spatial detailing at the threshold of furniture. We herein imply that intimate spatial detailing

such as a built in mezzanine or a sky lit shower are crucial elements in our recognition of architectural quality, particularly in our understanding of a specific space as our *home*. The bath in Corbusier's 'Villa Savoye' or the built in seats in Schindler's 'Lovell Beach House' are examples of this interior quality of *home*, a level of detailing which is seldom represented in the prefabricated house. These are unique examples which can be considered spatial experiments expressing the architects' spatial visions, and therefore have no direct relation to prefabrication. However, it is our belief that they are significant in developing a general understanding of architectural quality and that *interiority* is therefore also crucial as a point of departure in the development of future prefab solutions. As described by Charles Rice, the term *interiority* initially described our inner subjectivity; it was not until the middle of the eighteenth century that it became related also to the interior of a physical space as studied by Mario Praz (Rice 2007, Praz 1964). In this paper we understand *interiority* both as a spatial and as a constructive architectural matter: Spatial, in the ability of architecture to furnish an experience of being inside as opposed to outside, for example an embracing window-seat letting the user sense his or her *home* as in Schindler's build in seats. Constructive, in the way such experiences are a result of our constructive ability to join building elements, such as in Corbusier's endeavor to develop the spatial potentials of reinforced concrete. In continuation hereof it is the goal of the paper to examine whether *interiority* can be developed as a tectonic theory and design principle for transforming constructive challenges into sensuous spatial detailing in a future prefab *home*.

Figure 2. Interior 'Lovell Beach House' 1922-1926. (photo courtesy of the Architecture and Design Collection, University Art Museum, University of California Santa Barbara (Smith & Darling (ed.) 2001).

2 THE INTERIORITY OF CONSTRUCTION

2.1 *Methodology*

Through the introduction and formulated hypothesis a spatial critique and need for increasing the spatial detailing of the prefabricated house has been stated. In the following a constructive reason and framework for developing this critique in relation to the constructive and practical context of prefabrication is endeavored. Consequently, the paper addresses the origins of construction at a theoretical and practical technical level. Methodologically this is pursued through a deductive study of the theories and works of Gottfried Semper and Werner Blaser. Semper born in 1803 was a German architect, art critic, and theoretician and Blaser born in 1924, is a Swiss architect, photographer, and writer. In the mid eighteenth century Semper studied the origins of construction in search for a tectonic theory of architecture, based on his formulation of 'Four Elements of Architecture' (Semper 1989). These studies will be used as a basis for discussing the interrelation of space and construction in relation to the practical reality of prefabrication by comparing Semper's theories with Blaser's recent studies of the physical interrelation of space and construction manifest in the joint (Blaser 1992).

2.2 *Gottfried Semper and the duality of the enclosure*

In his historical studies concerning the origins of construction, Semper focused on the primitive conditions of architecture, what he defined as Urzustände (Semper 1989: 102). These conditions

Semper connected with the development of man's technical skills, linking these with the origins of architecture. Especially focusing on the techniques of pottery and weaving, by Semper defined as the earliest of techniques, he began to pursue a general understanding of architecture; a comparative theory based on these techniques. With his particular interest in construction understood as *enclosure* of space Semper's theoretical findings came to differ from his contemporaries' stylistic discussion. In opposition Semper claimed, that in its outset, architecture is independent of construction as an exterior monumental form, rather it is preconditioned by a need for a soft wrapping of the body utilizing the softness of woven textiles in the interior furnishing of a *home.* (Semper 2004: 247). It is this specific spatial focus which makes his theories relevant in our study of the *interiority* of construction here.

Semper's grand idea for a comparative architectural theory remained in the form of a prospectus. However, section V of his essay on the four elements of architecture can be looked upon as a summary of his comparative theory (Semper 1989:19). Herein Semper's interest in pottery and especially weaving as techniques manifested itself in a claim for a necessary representation of inner life, *home,* and the outer life as a formal construct of the initial spatial idea of construction. These studies led him to the formulation of 'Four Elements of Architecture'; the *hearth*, the *roof*, the *enclosure* and the *mound*. Here Semper especially noticed the conditions of the enclosure as being related to the technique of weaving based on his observation that the carpet in its capacity as a wall signifies the evolution of certain architectural forms (Semper 1989:103). This observation led Semper to the conclusion that the technique of weaving is the source of the oldest forms of ornamentation, hereby implying that weaving as a form of construction plays an important role in the general history of art. Thus, through these observations on weaving, Semper conclusively described construction; as a sensuous spatial and a technical practical matter, in which the enclosure is defined dually as the space creating softness of the textile and the constructive hardness of the wall (Semper 1989: 104). It is our claim that this duality and need for interior softness can be rediscovered in the works of Corbusier and Schindler, and is a decisive element in trying to understand the qualities of these works. As an example Semper's idea of the duality of construction can be used as a means for describing how each apartment in the 'shelve' system developed by Corbusier for the Unité block, becomes more than just a shelf: Here the constructive elements meet in different furnishing elements allowing for storage, play and seats spatially connecting the interior of the apartment and the exterior terrace. This detailing allows for a sensuous bodily contact with- and experience of the space as a *home* paralleling Semper's idea of wrapping the body.

With reference to the before mentioned challenges of the prefabricated house Semper's theoretical idea of spatially dressing the interior enclosure pinpoints the need for sensuous impressions of *interiority*, supporting our initial hypothesis. Simultaneously the occupation with Semper's works suggests that the key to this detailing lies at the core of construction, even precedes construction. In Semper's theory this duality is, however, not necessarily to be understood as a direct result of the jointing of structural elements, rather Semper speaks of a soft and a hard layer in the enclosure (Semper 1989:104). Both in the case of Corbusier and Schindler their works often consist of several interrelating but precisely orchestrated layers. One example is Shindler's furnishing interior constructions in plywood or other easily adaptable materials. These are seldom direct structural elements, but are significant in adapt ting the hard outer structure of the wall or load bearing column to the softness of the body, always experienced as a crucial element in his Los Angeles villas. However, when considering prefabrication and the level of system and economy required here, the question is if the found necessary furnishing of a *home* can be related directly to the structural means of construction; to the actual jointing of constructive elements. In the following we will thus be addressing the technical challenge of jointing structural elements through an occupation with the works of Werner Blaser.

2.3 *Werner Blaser and the system of furniture*

Through his works and writings Blaser zooms in on the interrelation of architecture and furniture addressing a direct aesthetic and technical relation between the two (Blaser, 1985:9). Motivated by the idea that furniture consummates the architectural unity of a house, Blaser has been tracing this relation historically comparing furniture and architecture through time. Due to his particularly focus on the joint, his work has by Katharina Steib and Arthur Rüegg been precisely

described as a 'systematology' of furniture making (Blaser 1992:8) It is our observation that this 'systematology' parallels Semper's strive for a comparative architectural theory based on extensive analyses of the development of man's technical skills. Herein Blaser uses the joint as a critical perspective trough which to analyze common factors in works of different eras. However, to Blaser the development of an understanding of architectural aesthetics is not a theoretical endeavor. Rather, Blaser has stated that his interest lies within the practicality of architecture and furniture as an aesthetic and technical unity, a unity inextricably linked through the joint (Blaser 1992:10). According to Blaser architecture does not acquire its identity exclusively in the creation of form, rather it is a result of our ability to solve the basic problem of integrating architecture and furniture into a total 'artistic expression' (Blaser 1992:10). For Blaser the means for arriving at this expression are deeply rooted in a technical and practical engagement with the joint. It is this systematic and practical linking of the technical and aesthetic dimensions of the joint which is of our interest here with regards to prefabrication.

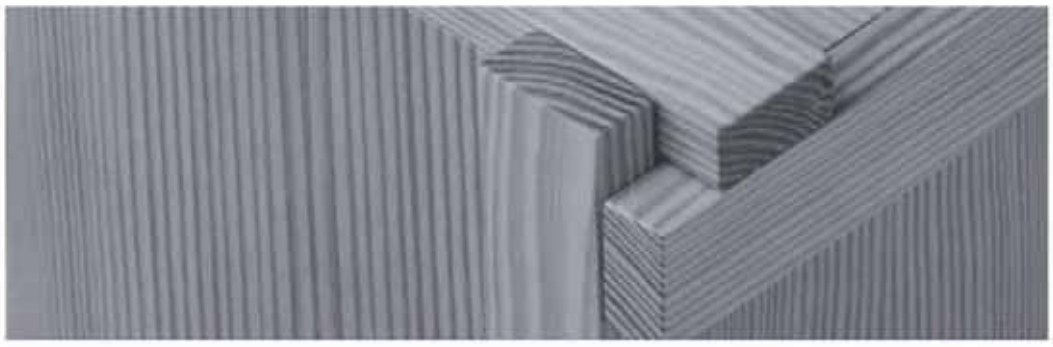

Figure 3. Wooden furniture joint by Werner Blaser (photo by Werner Blaser, published in (Blaser 1992)).

In his book from 1985 entitled 'Furniture as Architecture' Blaser compares this described aesthetic and technical interrelation of architecture and furniture over time. By focusing in on the joint Blaser draws connections between examples from the classical era, Charles Rennie Mackintoshes' geometrical and precisely staged wooden interiors and furniture designs, and Mies van der Rohe's architectural steel works and furnishing of the open plan. Here Blaser uses his particular skills as a designer and as a photographer to monitor the joint and its relation to the chair in furniture design and to construction and the articulation of space within architecture. These precise studies of the joint has resulted in the development of a 'system' of furniture making, described in the book of 1992 entitled 'Joint Connection'; a manifest based on Blaser's lifelong interest in the joint (Blaser 1992). Here Blaser's preceding studies are summed up and illustrated by means of his own furniture designs. With his travelling in the USA and Japan as a point of departure a number of physical answers to Blaser's occupation with the joint is here presented. By systematically looking at the structural elements of construction and their means of connection Blaser's studies unfolds a library of solutions to the basic problem of the joint. His illustrations of the joints; strut connected to strut, strut to plane, plane to plane etc. are prototypical solutions and architectural exercises exemplifying these necessary architectural techniques. To Blaser the key to architectural aesthetics lies in the simplicity of the joint and the architeet's ability to relate the aesthetic solution of the joint to the means of manufacture (Blaser 1992:10). By working his way from the smallest part of construction, the tenon, Blaser aims for the development of one simple joint forming the basic system for larger constructions, a system based on the *interiority* of construction.

Seen in relation to the context of prefabrication and its inherent need for economic and systematic solutions, it is our claim that Blaser's approach to construction can be understood as an architectural means for improving both the aesthetics and the technical logic of construction. With his idea of developing a single joint Blaser's furniture designs exemplify how the joint as a principle can create multiple spatial solutions; a seat, a table, storage units etc. The same approach could be imagined applied in the prefabrication of houses, and the development of such a system has been pursued in many layouts previously, intended to unfold a flexible building

envelope. However, in the case of housing it is our observation that this approach has achieved less success. As examples systems like Jørn Utzon's 'Espansiva' or Arne Jacobsen's 'Kubeflex' both of the 1970's published in (Bergdoll (ed.) 2008, Thau & Vindum 1998) seem to have failed as spatial articulations of *home,* when compared with other renowned works of the same architects. When scaled up to the dimensions of the house the sensuous qualities of the furniture joint are often lost. Consequently, the 'Espansiva' system was well developed as a technical system but consisted of so many parts that the spatial characteristics seemed lost in the puzzle. Likewise the 'Kubeflex' system, constructed as complete cubic volumes connected by a jointing mechanism, remained interesting as a system, but quite uniform in their interior. Inside the 'Kubeflex' house it is Jacobsen's renowned and expensive furniture designs which makes the space, whereas the spatial frame seems stiff and unengaged. Both 'Espansiva' and 'Kubeflex' remained prototypes and never reached mass production.

Figure 4. 'Kubeflex' interior with joint mechanism projecting into the space along the wall to the left.

In comparison with the detailing described earlier characterizing the works of Corbusier and Schindler, this pure system-approach lack spatial resistance in the form of sensuous elements narrating the bodily and spiritual act of sitting, eating or bathing. Also when compared with Semper's dual definition of the enclosure, they seem to be moving away from the creation of space and into the technicality of construction. However, Blaser's geometrical approach is an inevitable architectural means in economizing and shaping the constructive framework of the house. Even though the solution of the joint may be insufficient as a *home* in itself, Blaser's studies pinpoint the necessity of the architect's structural and geometrical skills: A knowledge which, especially within the context of prefabrication, preconditions spatial exploitations. The question is, however, to which extend the theoretical need for furnishing detailing of space can be integrated with the constructive need for a systematic practical solution of the joint.

3 PREFAB THEORY AND PRACTICE INTERIORITY AS A TECTONIC FRAMEWORK

As argued above prefabrication seems to be paradoxically dependent on our ability to look at the *home* as a system. In its outset this can be seen as opposing the initially described and desired inherent empathy of the *tekton*. However, when combining the specific understanding of the *interiority* of construction developed by Blaser with the necessary spatial *interiority* of enclosure studied by Semper, a theoretical potential for developing a tectonic *relation* between *home* and system opens up. In summarizing the preceding studies in relation to our initial hypothesis, construction can be understood as space and the joint as a furnishing element. Consequently, we can consider *interiority* not only as an intuitive expression used in an initial attempt to describe the quality of space but also as a theory and design principle. In this way we can begin to approach the development of practical means for transforming the constructive prefab challenges described by Gilbert Herbert in particular (Herbert 1984).

First and foremost prefabrication differs from traditional construction in being dependent on the assembly of prefab elements of varying sizes, for example wall floor and ceiling elements are prefabricated as planes assembled into complete volumes suitable for truck transportation

and on-site assembly (Bergdoll (ed.) 2008). In this process not only the traditional construction drawings such as plans and sections are insufficient; the construction of each element and the assembly of that element with the next calls for a completely different approach. Rather than the slowly progressing layer by layer and gradual adjustment technique of traditional construction, it is our claim that prefabrication calls for a geometrical approach. An approach inspired by Blaser's furniture joints; a system securing a fast and precise tolerance adopting assembly process. Herein also lays the idea of articulating these necessary joints rather than trying to 'erase' them with paint or plaster in an attempt to achieve for example a continuous ceiling imitating traditional construction, rather than developing a specific prefab aesthetic.

Jacobsen's 'Kubeflex' should here be mentioned as an example. Consisting of equally sized square modules, the house was assembled using an assembly mechanism which was added between the boxed elements, as shown previously on figure 4. This mechanism projects about 15 cm into the interior along the walls and ceiling in each module line, spatially and visually dividing the individual boxes. However, as concluded above the technical quality of this solution does not significantly affect the sensuous and spatial qualities of the house. In the utilization of *interiority* as a critical frame we can, however, begin to decipher the reasons why systems like 'Kubeflex' or 'Espansiva' are not inhabitable in the way Corbusier's 'Unité' shelves are. When held together with the described spatial qualities recognized here or in Schindler's projecting furnishing elements, *interiority* becomes a critical means in our historical study of prefabrication. Not only is a need for a geometrical and logic approach to the question of the joint inspired by Blaser hereby suggested, but also an actual spatial exploitation of the joint; a spatial adaptation of the load bearing structure to the softness of the human body as argued by Semper. Following this line of thought one could have imagined Jacobsen's joints as spatial furnishing details, fitted with cushions or textiles, rather than mere visual elements. Hereby his expensive furniture would become superfluous, but the initial modernist dream of producing economic prefabricated *homes* for the general public would maybe be within reach.

Figure 5. Interior of 'Le Cabanon' of 1950-1952.

Thus, motivated by an intentional focus on the need for sensuous detailing at the threshold of furniture, we are hereby able define *interiority*, as a theory and design principle for developing novel prefab solution: A theory not solely understood as a visual aesthetic occupation with the solution of the joint, but as a direct positioning of spatial *interiority* as the sole purpose and goal of these solutions. When looking at the window, in Corbusier's wooden 'Cabanon' it is obvious that it is our responsibility as architects to look at every joint as a potential to move outside box. This window is not just an opening to the exterior it is also a mirror fitted with such elegance and curiosity that as a visitor in this *home*, one cannot resist touching it. In total it is a furnishing element adjusted physically by the hand to project the light and the view inside, making the 'Cabanon' engaging and almost alive. Especially within the economic context of prefabrication, the architect is often the users only advocate in addressing this necessary *interiority*. By endeavoring Blaser's geometrical skills we may improve our ability to transform the constructive challenges discussed around the project table into details approaching the softness of the body as described by Semper and experienced in le Corbusier's 'Cabanon'.

As described by George H. Marcuse in his book 'inside the Machine for Living' 'Le Cabanon', built at the same time as the 'Unite' in Marseille, can be looked upon as a condensed abstract summarizing Corbusier's lifelong architectural endeavor (Marcus 200:177). The 'Cabanon' clad with rough split logs on the exterior is *solely* an interior: A *home* so simple with regards to economy and means of construction on the one hand but so indescribably rich on spatial experience and empathy on the other, that it is an example to be succeeded.

4 CONCLUSIONS

The goal of this paper has not been to define quantifiable rules of construction; rather, it has been to zoom in on the sensuous aspects of *home*, stating whether *interiority*, can be developed as a theory and design principle, usable in the development of novel practical prefab solutions: A theory for how to strengthen the architects' constructive and spatial abilities simultaneously improving our tectonic ability to visualize these aspects in the construction process.

Through a deductive study of the works of Semper and Blaser we have progressed from an initial hypothesis describing a spatial need for increased spatial detailing into the development of specific practical means for achieving this *interiority,* in future prefab solutions. If continuing this idea of transforming the joints, the problem areas of prefabrication, into spatial furnishing elements there is a potential to arrive at a new principle for spatially organizing the prefabricated house. Herein the interior of the monotonous square boxes could be divided and differentiated by spatial furnishing elements rather than plain walls. The utilization of novel CAD/CAM technologies could be imagined integrated here as a future means for refining and developing this concept further. At the scale of furniture rapid prototyping of complex forms may be feasible. Thus, as a research result the paper has shown that the concept of *interiority* can be developed as a tectonic theory and design principle for uniting *home* and system in the development of novel prefab solutions. Herein a practical spatial exploitation of the actual prefab construction is suggested, defining *interiority* not solely as a visual occupation with the joint, but as a direct spatial transformation of the joint in a furnishing spatial approaching of the human body.

5 ACKNOWLEDGEMENTS

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Thau, C. & Vindum, K. 1998, *Arne Jacobsen*. Copenhagen: Arkitektens Forlag.

4.4 'The rear mirror'

After having arrived at a solution for the sandwich construction itself and for the development of a building system which was not only economically feasible but which also contained significant architectural potentials which I was eager to pursue, we were as mentioned still struggling to fund further development not to mention to solve the fire resistance issue. The challenge in this relation is that whereas the construction will theoretically be able to withstand fire without collapsing, the insulation will begin to melt causing it to fail legislations. The problem can be solved by increasing the thickness of the concrete; however, this solution would cause the expenses and weight of the elements to increase unacceptably. Instead we had to work on alternative solutions which proved both costly and challenging as the Danish legislations on that particular area are based mainly on achieving fire resistant constructions rather than on fire extinguishing equipment such as for example sprinklers. For example in the US domestic sprinklers are not uncommon unfolding a potential solution to the problem which could likewise increase the safety, but so far a completely unapproved solution in Denmark. Yet another solution could be to introduce another insulation material, however again we did not find any economically feasible materials enabling this to become a feasible solution. While struggling with this fire issue we likewise worked simultaneously on the sketches for the prototype house, for its spatial detailing, energy consumption, principles of installations etc. see page 55, 57 and 87. However, despite our efforts, time was also beginning to run out. Less and less resources were left for the development project, instead all possible manpower had to be focused on keeping the general production of the original wood frame houses alive. At first the factory facilities at Boel Living A/S were closed down, secondly, we had to face the fact that we had run out of funding for continuing the development of the sandwich construction and building system by the summer of 2010.

With regards to the PhD research I also had to face the fact that we were neither going to achieve the practical results which I had hoped for, nor our common and not to mention real goals at the factory. Despite being very close to achieving the funds to produce a prototype house to be shipped as a test design for a low cost house for South Africa we eventually neither had funding to actually cast it, nor room in the general production of wood frame houses at the factory at Hjem A/S to continue our experiments. This general production had to be kept at a maximum in order to ensure the future survival of the company. Facing up to these facts completely pacified me, for several months in the early summer of 2010 it even affected my concurrent theoretical work, which did not make sense to me if doomed to remain theory. In the rear mirror definitely a both naïve and spoiled reaction, which makes me embarrassed today: Not only was that which had been a case study for me the reality for the employees at the factory; at a general level our goal sets, both my own research goals and the real goals which we had to achieve at the factory, were too high in comparison to the time and resources available. When seen in this light we actually made it quite far, even though that is cold comfort. The fact that we did not make it to the finish line and the consequences which that had at the factory, where also the general production of prefab houses had a hard time surviving, however has been and still is extremely hard to accept. Finally, I however realized the obvious, namely that experiences gained are never useless and began to think of these as a case for further studies instead. In continuation of the above observation that in the intense process surrounding the development of the sandwich construction my initial architectural goals was to some extend pushed into the background, and I consequently made a promise to myself to spend the last months of the PhD focusing on strengthening the theoretical architectural foundation. The fourth and final paper which I have chosen to include here exemplifies this return to the 'roots' of the research so to speak.

Model of the intended prototype house, 110 m2, spring 2009

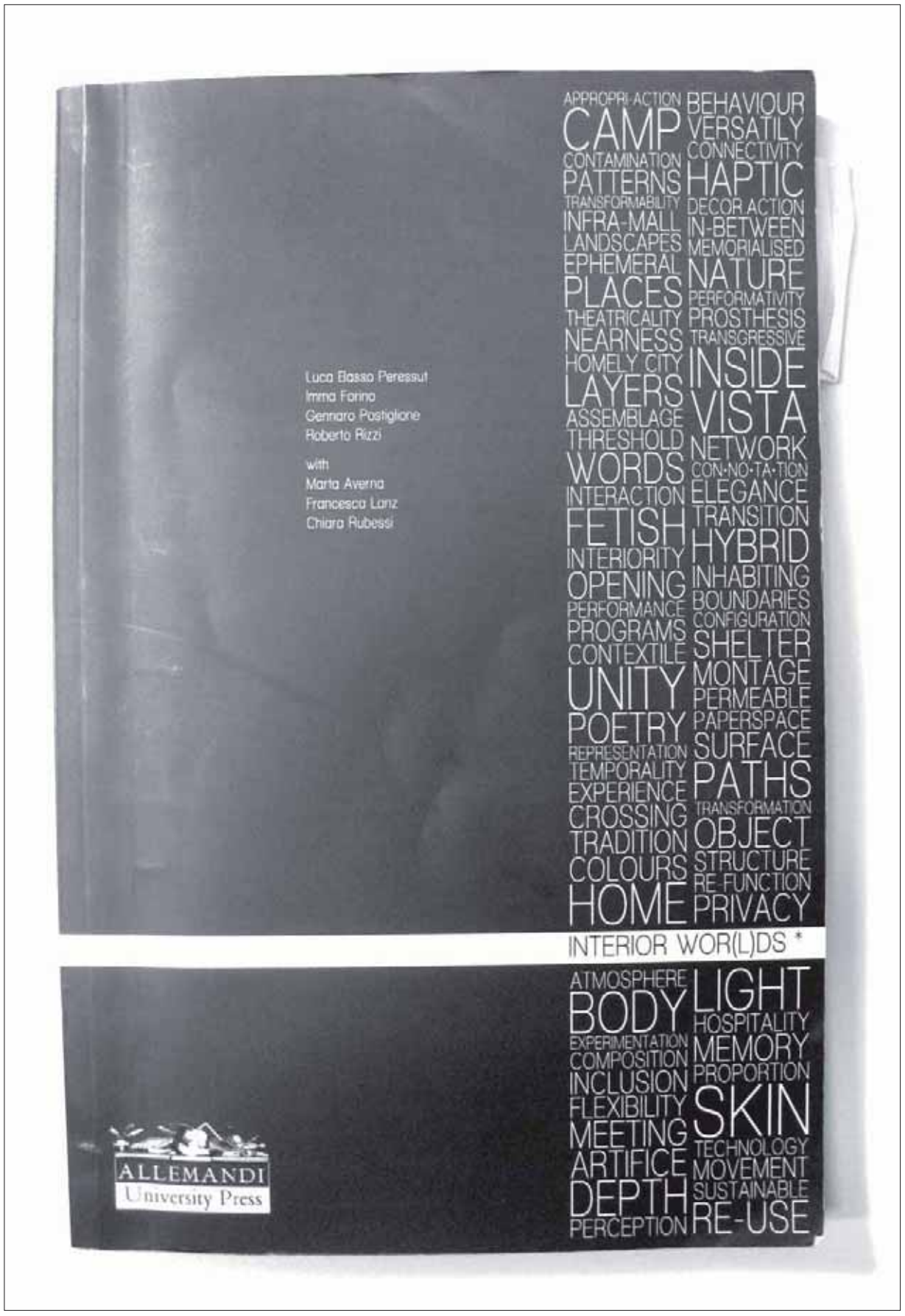
Paper 4:

'INTERIORITY'

Published in 'Interior Wor(l)ds, Umberto Allemandi & Co., Torino, 2010

This paper was presented and simultaneously published at the 'Second Interiors Forum World International Conference' at the Politecnico di Milano in October 2010. Entitled simply '*interiority*' the paper can be seen as the first attempt to summarize and articulate the results of the theory development which has eventually found it's hitherto full extent in the monographical first volume of the PhD thesis. Here the first steps were taken towards the development of a conceptual framework and analysis method enabling an actual description and explanation of the notion of *interiority* which had up until then remained more of hypothetical claim than a thoroughly reasoned argument. The paper contains an example of the analyses which have later become fully developed Chapter 5 of Volume 1.

Especially the initiation of a more thorough discussion of the proposed utilization of furniture as an architectural parallel and concept eventually led to the development of a more tangible understanding of the potential of *interiority*. This simultaneously allowed me to begin explaining the domestic architectural qualities of for example Corbusier's villa Stein, which I had used several times as an example, however, without being able to explicitly exteriorize the source of my appreciation of it. Beginning to actually conduct such theoretical analysis of *interiority*, rather than go around it, as I admit having been doing eventually also led me closer to an uncovering of its constructive and technical practical application, which I am still not willing to leave untouched.


APPROPRI-ACTION
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HOMELY CITY
LAYERS
ASSEMBLAGE
THRESHOLD
WORDS
INTERACTION
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INTERIORITY
OPENING
PERFORMANCE
PROGRAMS
CONTEXTILE
UNITY
POETRY
REPRESENTATION
TEMPORALITY
EXPERIENCE
CROSSING
TRADITION
COLOURS
HOME
BEHAVIOUR
VERSATILY
CONNECTIVITY
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NETWORK
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Gennaro Postiglione
Roberto Rizzi
with
Marta Averna
Francesca Lanz
Chiara Rubessi
INTERIOR WOR(L)DS *
ATMOSPHERE
BODY
EXPERIMENTATION
COMPOSITION
INCLUSION
FLEXIBILITY
MEETING
ARTIFICE
DEPTH
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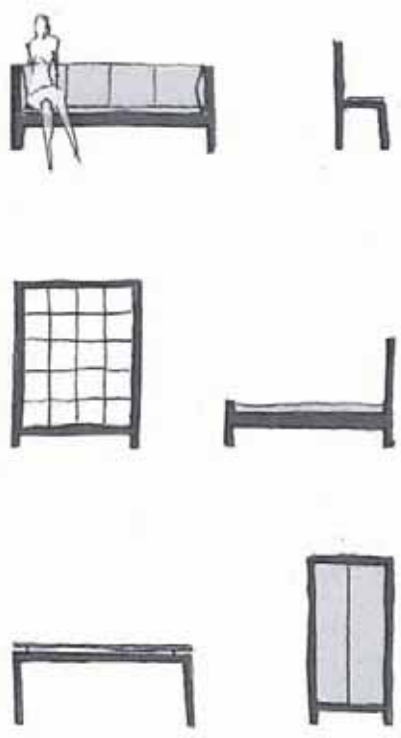

Interiority

Marie Frier, Anna Marie Fisker and Poul Henning Kirkegaard
Aalborg Universitet (Denmark)

Using our senses we intuitively recognize the inviting *interiority* of the precisely orchestrated interiors of, for example, Mackintosh, Loos, Le Corbusier, Wright, Schindler, Aalto and Fehn. In the sensuousness of these works, we experience how *building envelope* and *furniture* merge as a result of a deliberate engagement with functionality and scenography in the transformation of the *building envelope* into *furnishing* spatial elements inviting the inhabitant to see, touch, hear, smell and taste *home*. Such detailed spatial engagement with the intangible concept of *home* is, however, easily disregarded within the increasingly complex practical, economic, and climatic realm of architecture leaving our houses as raw *constructions*. Consequently, this paper investigates whether the perceived interior qualities of the previously mentioned works can be articulated and activated as principles in a future positioning of *interiority* within today's practical realm. A preliminary research result discusses *interiority* (1) as a theory and design methodology for transforming the actual structural and economic elements of *construction* into *furnishing* details, signifying *home*.

Fig. 1.
Furniture: sofa, chair, bed, shelf, table, and closet.

The increasingly complex processes affecting society today pose new demands on architectural practice. Especially within domestic architecture, where prefab processes have for over a century been envisioned as the means for achieving a general improvement of the ordinary dwelling, the sensuous furnishing aspects of architecture are often pushed in the background, leaving the produced houses as raw *constructions* rather than sensuous inviting *homes*. (2) Consequently, is seems that one of the greatest challenges for architecture as a discipline is to increase our involvement with industry, herein our ability to actualize, communicate, and develop the sensuous aspects of *home* within the processes preconditioning practice. The question is, however, how to define and articulate the rather intangible concept of *home*.

Through our sensuous perception we intuitively recognize the soft upholstered *interiority* of furniture, described by Praz as a

(1) In the 18th century dictionaries the term *interiority* initially described "inner character"; it was not until later that the term became related also to the interior of a physical space (Rice 2007, 2). Thus, when utilizing the term here we are not only suggesting a necessary venture into a boundary field interrelating that of *building envelope* and *furniture*, but also interrelating senses and mind.
(2) Herbert 1984; Arieff and Burkhart 2003.

precondition for our experience of a place as *home*: (3) a *interiority* which is our claim, can be rediscovered as a spatial discipline interrelating *building envelope* and *furniture* in the precisely orchestrated Functionalist interiors of, for example, Mackintosh, Loos, Le Corbusier, Wright, Schindler, Aalto and Fehn. Here details such as built in seats and niches create points of actual sensuous interaction with the house, details in which wall and chair merge as a result of a deliberate engagement with functionality and scenography inviting the inhabitant to see, touch, hear, smell and taste the *interiority* of the house as *home*. Not only do they provide for functionality embracing the senses, it is our belief that they also stage the complex pleasures of the mind such as in Mackintosh's choreographed meeting of male and female in precisely defined niches demarked by his high-backed chairs. These works can be considered total works of art, built under conditions which are radically different from the ones governing the ordinary dwelling. However, it is our hypothesis that they contain crucial principles necessary in attempting to spatially define the intangible concept of *home*. (4) Consequently, it is the goal of this paper to investigate how the perceived *interiority* of these works, having kept their relevance in the present, can be articulated and activated in a future positioning of *interiority* as an architectural theory and design method for transforming the structural and economical elements of *construction* into *home* in the ordinary dwelling. Methodologically this is pursued by attempting to utilize *interiority* as an analysis-method, pursuing a testing of the particular hypothesis that a single furnishing element contains the seed for *constructing* a *home* in its entirety. (5)

Interiority as an analysis-method

In Unwin's *Analyzing Architecture* his notion of "architecture as identification of place" has led to a listing of specialized analysis-parameters; *stratification, transition, hierarchy*, etc. (6) In a similar manner von Meiss and Arnheim uses notions such as *order, disorder, solid, hollow etc.* in describing architecture. (7) However, rather than attempting to describe the architectural work and the instruments at play in their entirety, it has been our strategy here, to look at architecture-analysis in a more immediate manner; from the point of view of the chair. Herein we use *interiority* as a critical perspective through which to dissect the spatial principles governing our sensuous experience of *home*. In this matter we have begun by zooming in, first on the concept of *furniture*, hereafter on the *building envelope* and finally their interrelation, *interiority*, using Corbusier's Villa Stein as an analysis-example. (8)

(3) Praz 1964, 24-35.
(4) Here it should be mentioned that a study of the subtle differences between these architects' approaches towards the interior is worth a study in itself. However, in this paper we try to uncover and articulate similarities in their underlying principles at a more general level.
(5) The material presented summarizes parts of the PhD project "Interiority – Architecture in the Future Prefabricated Home." A research project pursuing a development of the concept of interiority, not solely as a sensuous-aesthetic matter as argued by Praz and many others (Praz 1964; Rice 2007; Taylor and Preston 2006), but also as a constructive-technical means. Through a combined theoretical and practical research strategy a development of interiority as a theory and design method for transforming constructive challenges into furnishing details, improving the sensuous quality of the prefabricated home is herein pursued.
(6) Unwin 2003.
(7) von Meiss 1998; Arnheim 1977.
(8) Works such as Villa Moller, Fallingwater, and Villa Stein are examples which have become icons, known by architects and to some extend even by laymen. However, as described it is our hypothesis that there is still reason to address these works in a search for principles of interiority; elements necessary in approaching a spatial definition of home. Many before us have been examining these particular works of which (Risselada 1988; Rizzi 2003) are just two examples of reference-material used in our studies.

Fig. 2.
Building envelope: floor, wall, roof, window, and door.

Furniture

As described by Lucie-Smith there exist an endless number of furniture variations, dining-tables, sofas, bookcases etc. However, all of which derive from one of the four typologies; pieces on which to sit, put things, sleep or recline and pieces in which to store things. (9) One could say that furniture unfolds a sensuous invitation, "serving our bodies and possessions" to use the words of Abercrombie, who defines two basic typologies of furniture; one serving our bodies, *sofas, chairs,* and *beds,* and one serving our possessions, *shelves, tables and closets* as illustrated in fig. 1. (10) Pieces of furniture are mobile elements wherein our bodies and our things can rest upon surfaces and inside cavities, often upholstered, offering a soft encounter. Brayer has argued that a chair is immediately inhabitable, "a symbol of the dwelling", as an effect of this particular softness and proximity to the human body. (11) However, there are also differences between chair and house.

Building envelope

In opposition to the mobility of *furniture* the *building envelope* once erected is in general fixed. Rather than supporting and serving our bodies and possessions, it shields us against the weather, basically consisting of *floor, wall, roof, window,* and *door* as exemplified in fig. 2. However, as described by Semper in his studies on the origins of *construction* the house evolved first and foremost as an enclosure preconditioned and derived from the technique of weaving. (12) Thus, whereas in general we think of the house as a framework large enough for us to stand up and walk around in, it derives from the principle of dressing, describing a proximity to the human body even more intimate than that of furniture and opposing the raw *constructions* making up our houses today. We cannot only conclude that the softness of furniture preconditions our experience of a place as a *home* as stated by Praz, but also that the actual technique for *constructing* the house derives from this particular intimacy. Thus, rather than looking at furniture as a mobile addition to the fixed building envelope and an autonomous discipline, we can begin to look at *furniture, building envelope* and *construction* as being interrelated architectural dimensions of the *home*.

Interiority

In interrelating *furniture* and *building envelope* as proposed above, both are transformed. Rather than being mobile the chair is now

(9) Lucie-Smith 1979, 8.
(10) Abercrombie 1990, 80.
(11) Brayer and Simonet 2002, 42-43.
(12) Semper 1989, 74-130.

Fig. 3.
Interiority; a place to sit, eat, sleep, bathe, and synthesize.

Fig. 4.
Isometric drawing of spatial element in Villa Stein.

(13) In his privacy Le Corbusier kept a collection of found objects, some kept because of their functionality such as the two whisky boxes used as stools in Le Cabanon, others kept for less tangible reasons, such as a pebble which he thought of as a self-portrait (von Vegesack et al. 2007 p. 142). Thus, not only was Le Corbusier architect of grand-scale urban visions, he also appreciated the smallest of things. It is our claim that his interiors invite us, not only to move in with our possessions, but to interact with the spatial elements of interiority in creating our home.

contextualized accentuating particular qualities of the house. The chair is no longer just a piece on which to sit, it becomes *a place* in which *to sit*. Likewise the house is no longer a raw *construction*, but contains sensuous *spatial elements* inviting the inhabitant to sense the house as a *home*; *places* in which to *sit*, *eat*, *sleep*, *bathe* and *synthesize* as illustrated in fig. 3. Thus, after having zoomed in, first on *furniture*, subsequently on the *building envelope*, we can now attempt an actual formulation and testing of *interiority* as an analysis method. Looking at Villa Stein as an example, we can hereby direct our analysis to particular spatial elements, points of encounter between furniture (*sofa*, *chair*, *bed*, *shelves*, *table*, and *closet*) and building envelope (*floor*, *wall*, *roof*, *window*, and *door*). Fig. 4 shows how the spaces in Villa Stein actually evolve from the principle of a *shelf*. In creating a curvature contrasting the rigid constructive framework of the house, the *shelf* interacts with the *wall* in the creation of niches, bookcases, and seats, further slicing a hole in *floor* and *roof*, creating a visual contact to the storey below. One example is how the seat created by the *shelf* directs the inhabitants' attention towards the small window opposite the seat. Another is how the *shelf* wraps around the *wall* to the right creating a cavity serving as a sideboard on one side and as a decoration-shelf on the other. Thus, not only does Le Corbusier provide for functionality and sensuous encounters in the creation of a *place to sit* and *to eat*, but also for *places* of *synthesis*, for displaying our *object trouvé*, (13) objects signifying the complexity of the mind. We cannot only conclude that it is in this particular and deliberate transformation of the *building envelope* into *furnishing* spatial elements that the seeds for *constructing* the *home* in its entirety are to be found: But also that the specialized instruments governing architecture as a discipline are hereby made physical, and articulate.

Discussion

In returning to our examples, the works of Mackintosh, Loos, Le Corbusier, Wright, Schindler, Aalto and Fehn, we can conclude that they do not solely represent an exclusivity unknown of the ordinary dwelling; they also contain precise and prosaic principles of *interiority*, thus making the significance of *home* physical and articulate both for the senses and the mind. The future challenge, however, is how to relate these principles to the structural and economic means of construction; *plate*, *shear wall*, *beam*, *column*, *bolt* and *screw*, illustrated in fig. 5.
We close the paper by proposing a development of *interiority* as a theory and design method for transforming the actual structural

Fig. 5.
Construction: plate, shear wall, beam, column, bolt, and screw.

elements of *construction* into *furnishing* details, asking whether it is possible for the softness of upholstery to evolve directly within the economy of *construction*? This is a challenge which not only requires a passionate engagement with the concept of *home*, but also with the practical realm of the ordinary dwelling: an inherent and increasing architectural challenge, which may be utopian in its destination, but which is nevertheless captivating and necessary.

The work presented in this paper is partly financed by the Danish housing manufacturer Boel Living A/S. In addition Boel Living A/S is our project partner offering not only a view into the practical realm of prefabrication but also an actual and engaging context for pursuing a practical testing of theory, a matter discussed further in a paper recently published in *Design Principles&Practices – An International Journal*, vol. 4, i. 2. The support is gratefully acknowledged.

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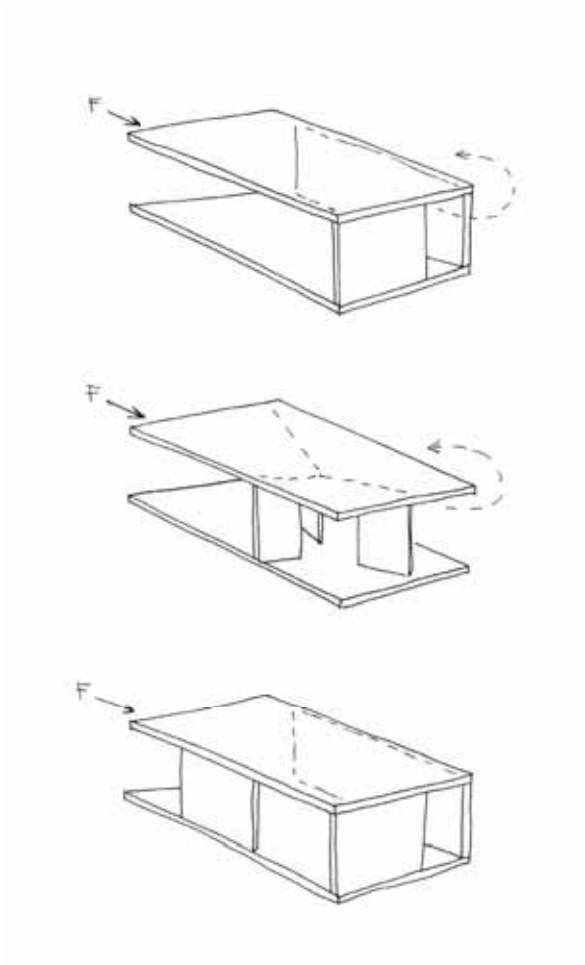
4.5 Summary

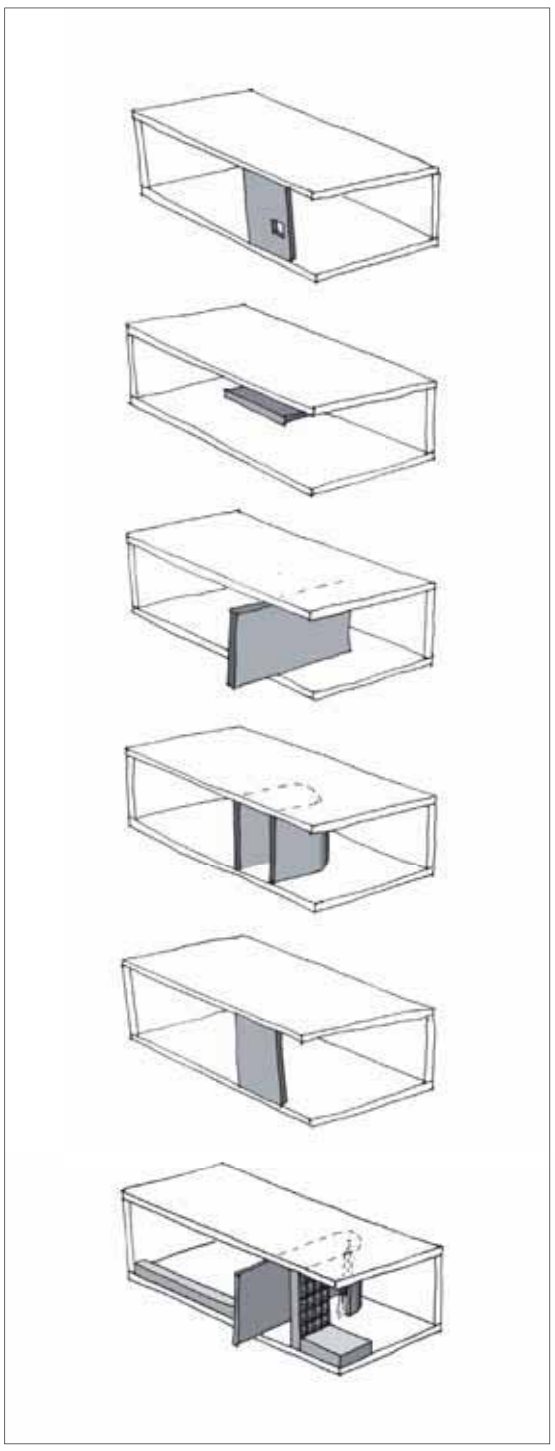
In summarizing the field studies which defined the actual practical attempts made within the PhD research to test and apply the developed interior theory it is inevitable that with regards to the practical results hereof I had hoped for more. I had hoped to arrive at actual improvements in the domestic architectural quality of the prefabricated houses produced at Boel Living A/S. Recalling the wording of the research question for the case study; I had hoped that the developed interior architectural theory of domestic architecture could have been activated and utilized as a critical means for transforming the economical and structural elements of construction into experiences of *interiority* within the particular practical context of the prefabricated house. However, whereas we achieved considerable results with regards to developing a detailed understanding of the economical and constructive conditions of the prefabricated house as well as the roles played by the various project parties involved herein, the study eventually led to a return to the theoretical roots of the research. If referring to Peirce's circle of inquiry which I initially adopted as the general methodological framework for my research this has been a case, not for a complete disguise of the theory but for refinement, for maturation. The field studies had affirmed the assumption that particularly in the prefabrication industry eventually the architect is the only possible advocate of articulating the user's needs. They had likewise affirmed the assumption that there is an increasing need for us as architects to improve our ability to involve ourselves in this industry and that such involvement not only entails a will to understand the economical and constructive premises of all parties in the process but also the responsibility to put the foot down and position the potential and necessity of architecture herein. Finally the field studies also showed why the application of architectural theory can never become predictable as the context of architectural practice can never become a controlled environment such as a chemical lab. It is subject to all kinds of external and internal influences making it problematic to generalize. In the case with Boel Living A/S the lack of funds forcing us to stop the experiments at the factory was a regrettable loss for all parties involved. From a research perspective the return to the theory development has, however, led to a refinement and maturation hereof, which is probably eventually more valuable as a point of departure for future developments than would have been a single practical result in the form of a house. I admit being still disappointed and sorry not to have reached that architectural result, mostly on behalf of the company, however, it is a fact that the conditions for continuing the development were non-existent.

The return to the theory development eventually led to the development of a conceptual framework and analysis method enabling an actual architectural description and explanation of the furnishing 'gestures' signifying our experience of *interiority* as unfolded in Volume 1. It likewise enabled an extract of the actual 'principles' from which these 'gestures' emanate. In referring to the research question enabling an approaching of a physical and tangible understanding of what it means to transform the economical and structural elements of construction into experiences of *interiority* within the particular practical context of the prefabricated house: Not only are we as architects in need of a structural understanding of the house as argued by Björn Normann Sandaker, having to understand 'The constructive basis of architecture'; how the house stands up, see page 97 (Sandaker 2008). The encounter with the practice at Boel Living A/S, where the interest in architectural quality was initially present has proved that in times of prosperity as was the situation when the factory opened in 2007 as well as in times of recession as it became the reality later, these qualities must be a direct and integral part of the economical and structural elements of construction to become a reality: They must stick directly to the technical and economical construct of the prefabricated 'box' itself. This is a realization which probably accounts for most of what we would entitle general construction. Unless what is being planned is a significant cultural building or a unique home for a wealthy client, there is seldom room for additions beyond the constructive framework itself. If we as architects want to have a say in this development and to affect the quality of the ordinary dwelling it is thus conditioned not only by a detailed understanding of its underlying structural and economical system but also by a simultaneous ability and insistence upon the functional and emotional potential of architecture.

With regards to the prefabricated house, still often stemming from the fabrication of a 'box', a typical house is often manifest in an equal distribution of spaces divided by means of a series of plain walls, a distribution in which the kitchen is experienced like the bedroom, which is experienced like the bathroom. In addition to this lack of spatial articulation, a structurally excess amount of walls are often used in defining equally sized boxes within the general box making up the house. In continuation hereof there is a need to reconsider the envelope also from a structural point of view: The prefabricated box itself has become an invective, however, it is my claim that fundamentally there is nothing wrong with the box, as long as it is a 'good' box, a box containing *interiority*. In order to avoid the lack of spatial quality, contrasts, hierarchy, and intimacy, for which the prefabricated house is often criticized it is our responsibility as architects to actually transform and utilize the structural and economical elements of construction in order to initiate such spatial hierarchy, contrast and intimacy. In trying to understand the minimum number of elements needed to construct the envelope itself, we may begin to investigate what happens when applying the 'principles' resulting from the analysis in the previous chapter to just one single constructive element, see page 98. As the analyses of the five emblematic examples of the described 'gestures' of *interiority* in the works of Mackintosh, Wright, Loos, Corbusier and Schindler has shown, such hierarchy may emanate from a single mark, bend, stretch, cut or elevation of an element of the spatial envelope.



Stability of shear wall and plate construction after (Sandaker 2008).



'Principles' of *interiority*.

Especially Corbusier has argued that once such hierarchy is established in for example the introduction of a raised mezzanine, the necessary *interiority* of the home can be developed with a minimum of means (Phaidon 2008 p. 45). Thus, solely by fitting the wall with for examples shelves we can begin to develop 'gestures' of *interiority* within the dwelling, not by adding more wall, but by articulating what is already there. Simultaneously development of these 'gestures' establish an orientation, stemming from its sensuous furnishing qualities, thus, establishing a relation between interior and exterior. From a general understanding of the system of construction we can begin to propose an actual exploitation of the constructive elements as making 'gestures' of *interiority* by means of detailing. As concluded in Volume 1, there can be no recipe as to how this is achieved, however on the other hand the means of achieving this spatial sensitivity are deemed to remain inarticulate if we do not as architect utilize our specialized knowledge and empathy to stand up for architecture: It is necessary that we put down our feet and try to show the way by insisting upon and articulating how for example a shear wall can for example 'embrace' or 'guide' us.

Within volume element construction which I have been studying here, the architectural potential is necessarily to be found in an exploitation of what is already there. We have to stop thinking about the plates and shear walls as well as the joints between them as plain walls and start approaching them to the human body; to the sensuous scale of furniture. Having the walls function as for example closets and to join them by means of for example shelves and tables and to never make a window without offering a seat from which to enjoy its view. The proposed spatial exploitation of the actual technical and economical elements of construction and their jointing likewise offers a means to introduce movable elements in the home, adapting it to different uses and moods. Likewise surface treatment offers a sensuous potential, a potential for adding soft upholstery or for articulating the characteristics of a material as it already is using very simple means. Either way it is our responsibility as architects to exploit this potential not to mention to spur it; to offer places within the house which 'move' the inhabitants and which they can actually physically 'move' into . Until now I have only reached a conceptual sketching of how this utilization of furniture as an architectural parallel can be applied in volume element construction. I am however determined to continue working on it. It is in this relation my hypothesis that the novel CAD/CAM and rapid prototyping technologies discussed earlier may actually become a powerful tool in developing this idea further. In large scale cultural projects where these technologies have up until know mainly been used they still struggle with the fact that in order to produce the magnificent shapes resulting from the digital environment, they eventually have to be divided into elements which are often in a paradoxical need of being manually welded on site in order to come alive. This is an issue which recent initiatives aimed at the development of parametric architectural systems in which the means of construction are directly embedded are pursuing means to overcome. At the scale of furniture, however, the application of rapid prototyping technologies seems more immediate and ready for implementation. I find that there lies a great potential in starting a more targeted exploration of these technologies as a means for developing the 'contents' which are so often missing in our poor everyday constructions.

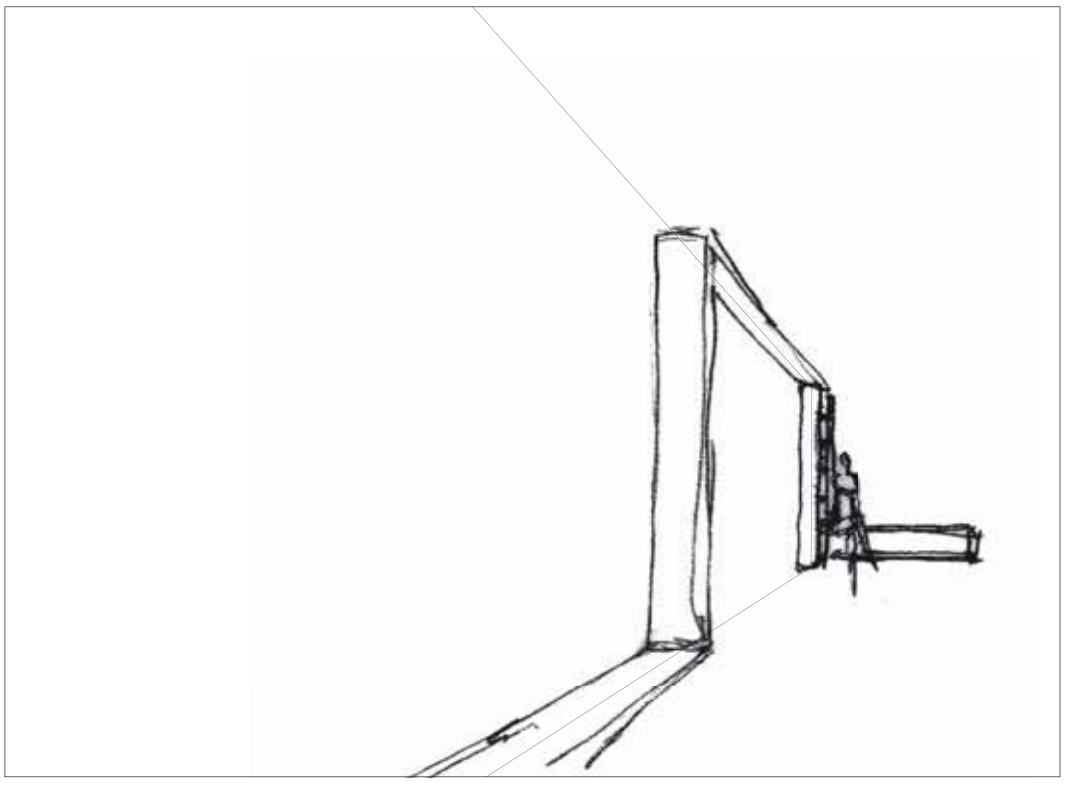
Chapter 5

CONCLUSION

AS STATED IN THE preface I pursued a PhD position in order not to detach myself from practice, but in order to gain means for approaching it, driven by the belief that architectural research can help improve our ability as architects to communicate and to mediate within the complex multidisciplinary context characterizing our practice. By engaging with the particular context of the prefabricated house as a case study for test and application of the developed interior architectural theory it has been the goal of this part of the research to pursue actual practical improvement of the domestic architectural quality of the prefabricated house in practice. However, as accounted for the actual physical architectural results are still a long time coming. This having been said I do not find that the case study failed. Rather it has proved that there is a need for us as architects to improve our ability to theoretically articulate the intangible concept of architectural quality, especially at the scale of the domestic, and to reveal it through a stubborn but most importantly empathic involvement with the complex multidisciplinary economical and constructive processes governing architectural practice. It has also proved that architectural research does hold a potential to help facilitate this development, which I would not have had the chance to explore had I limited the research to the theory development. With regards to the general research topic of domestic architectural quality the actual practical encounter with the practice of prefabrication at Boel Living has for good and evil exemplified the complexity of this practice. By December 2010 Hjem A/S went bankrupt and had to close their production of wood frame houses. I feel extremely sorry for the people who worked at the factory and for the owner Knud Boel Troelsen and his family who were all active in the business. I am grateful for having had the chance to participate in the ambitious and intense but nonetheless captivatingly exciting process surrounding the described sandwich construction and I still believe that someday we will find application of the results which we actually did achieve.

As stated above this encounter with prefab practice has equipped me with a respect for the implications of the call for *interiority* which is manifest in the theory development. However, with regards to its need and applicability it has only strengthened my belief. The fact that one of the only architectural parameters which we have succeeded in situating within most of the practice of domestic architecture is seemingly that it should be 'flexible' still makes me furious. It is not good enough! And despite the tight structural and economical conditions which are a prerequisite of this context, it is still my claim and research result that it is our responsibility as architects to facilitate a more nuanced discussion of what domestic architectural quality is and to insist upon its practical revelation herein. The ordinary dwelling is, as stated by Corbusier, our most crucial task as architects (Corbusier 2000; 1923). It is within the ordinary home that the ability of architecture to 'move' us finds its finest application. However, when considering the ordinary dwelling, it is likewise inevitable that the revelation of its' architectural potential is dependent on the development of effective means of production, just as it is a fact that these means will be utilized no matter whether or not there are architects involved in this production. If we as architects want to have a say in this development and to affect the quality of the ordinary dwelling it is thus conditioned not only by a detailed understanding of its underlying structural and economical system of production but also by a simultaneous ability and insistence upon the functional and emotional potential of architecture. If this insistence is not present we have already failed, as stated by Corbusier already in 1910 on experiencing the work of Behrens.

The above case study has shown that there are means for integrating home and system in the prefabricated house, and that the developed interior architectural theory can be activated and utilized as a critical means for transforming the economical and structural elements of construction into experiences of *interiority* within the practice of the prefabricated house. If continuing this line of thought one might begin to think of the complex technical module joints of the modules of for example Arne Jacobsen's 'Kubeflex' house pictured on page 9 as actual furnishing 'gestures' in themselves, rather than mere constructive details. This would make these cubes homes in themselves, eliminating the need to supply these volumes with Jacobsen's world known and expensive furniture; it would make *interiority* the responsibility and the content of the prefabricated economically feasible house itself. Hence, there is a potential that *interiority* can become a reality for the many. However, it has also shown that the road to the revelation of this potential may be long and bumpy. I nevertheless find it both necessary and exciting to pursue, and if I am ever to be offered a similar position in a development project I will not hesitate to accept.



Sketch for an actual spatial and furnishing utilization of the crucial module-joints, winter 2007/2008.

Chapter 6

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