Doctoral Thesis

# PROCESS- AND PROJECT-LEVEL ISSUES OF DESIGN MANAGEMENT IN THE BUILT ENVIRONMENT

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**ABSTRACT**

This thesis aims to advance theory in design management within the built environment. The main premise in this thesis is that the vast majority of management theory in the built environment has been dedicated to the construction field, which is substantially different from the design field. While the construction phase of projects is fragmented in a way that makes it appropriate for traditional project management philosophy based on hierarchical subdivisions of work scope, tasks in design consist in overwhelmingly-intertwining interrelationships that make design management substantially different from construction management. Departing from these characteristics, this thesis aims to delineate design management from construction management philosophies. The long-term result of this effort will be a coherent theory of design management tailored for projects in the built environment sector.

This thesis therefore, endeavors to answer the following research question. Why concepts from production project management do not work for managing multidisciplinary design in the built environment? The thesis seeks to answer this question by investigating the process-level characteristics of design decomposition and the project-level characteristics of design integration.

The answer to the question is therefore designed as a two-fold construct. The process-level answer to the research question elaborates task interdependence through a single case study and concludes that existing management frameworks do not take into account the specificities of design as a cognitive activity comprising problem-solving and interactive inquiry with the designed object. As a result task isolation is not possible in the way advocated by traditional project management. Instead, design should be viewed as a web of interdependence that needs to be managed using a mindset based on loops of cause and effect instead of hierarchical breakdown structures. The thesis validates the process level management framework with data from an in-depth case study conducted on a large-scale infrastructure project.

Based on the process-level characteristics, the thesis then reviews macro-level theories in sociology and economics to identify project-level integration properties of design management. Based on these properties, the thesis proposes and initially validates a

project-level design management framework based on the management of design expertise as a stream of knowledge transactions in the expertise market.

The thesis advances theory and practice in several ways. Firstly, on the basis of the literature review from different design disciplines, the thesis identifies the need to establish a domain-independent theory of design management and the corresponding professional discipline. Secondly, based on process-level interdependence in design, the thesis proposes to use a systems thinking based management mindset coupled with the corresponding methods, based on causal relationships. And thirdly, the thesis identifies the need to integrate design at the project level by using a flexible transaction-based representation of design, which also contributes to theory-building in the, thus far underrepresented, area of design economics.

The nature of theory built in this thesis is thus mostly descriptive with the main aim to broaden the understanding of the design processes and their management within the built environment. The descriptive nature of the results is a consequence of the substantial lack of knowledge in the area of design management and the general misuse of production-based theory in the area of cognitive activity. This research therefore fulfills its main goal of providing a solid basis and a direction for further research and practice in the area of design management in the built environment.

**PREFACE**

The seed of this research goes back to my stay at the Center of Integrated Facility Engineering (CIFE) in Stanford University in 2007-2008 hosted by Professor Martin Fischer. I am thankful to Martin for offering me the possibility to discuss my research interests not only with members of his group, but also for introducing me to the researchers at Collaboratory for Research on Global Projects (CRGP). Through casual acquaintances with researchers, I became profoundly interested in the social aspects of research in the context of engineering organizations. Here I would like to mention Professor Ray Levitt who greatly affected the shift in my research interests from the technology area to the social and psychological area. My stay at Stanford also enriched me through acquaintances with Dr. Timo Hartmann and Dr. Amy Javernick-Will, with both of whom I have continued collaborating closely since then.

Upon my return home, as I was in pursuit of collaborative and interdisciplinary research, I decided to enroll the doctoral program at the Institute of Industrial Building and Interdisciplinary Planning (BI.IBPM) in Vienna University of Technology thanks to Dr Iva Kovacic who acquainted me with the main supervisor of this thesis, Professor Christoph Achammer. Thanks to Iva and Christoph, I was able to continue my research endeavor in a collaborative manner, working at the interface between architectural and engineering design. They provided me, for instance, with the opportunity of choosing the doctoral courses from the University of Twente where I spent six months for that purpose.

Professor Christoph Achammer provided me with contacts in design organizations as well as with practical direction in critical moments of this research. Thanks to this guidance, I could much more easily put my theoretical thinking into the pragmatic context of real world problems. My second supervisor, Dr Timo Hartmann, on the other hand, took care of the scientific rigor needed in this kind of theoretical work. It is largely because of Timo's help, that my writing style acquired the shape it now has.

I would additionally like to thank the following people for providing feedback on different parts of this thesis: Dr Christian Brockmann, Dr Paul Chan, Professor André Dorée, Professor Geert DeWulf, Professor Lauri Koskela, Dr Rachel Luck, Professor Roberto

Pietroforte, Dr Peter Raisbeck, Dr John Taylor, Professor Jennifer Whyte, Professor Graham Winch, and Professor Hans-Georg Gemünden.

I am particularly grateful to Professors Geert DeWulf, Ad den Otter, and Jennifer Whyte for inviting me to present and discuss my work in departments and research centers in Twente, Eindhoven and Reading.

I am thankful to all of my colleagues from the Department of Construction Management and Economics, Faculty of Civil Engineering, University of Zagreb for several particular reasons. Firstly, my entire doctoral research was funded through my Department in Zagreb and the Croatian Ministry of Science, Education, and Sports. Secondly, because of the open-mindedness of my Croatian supervisor, Professor Jadranko Izetbegović I have been receiving full-time support for conducting PhD research in an unusual arrangement. And finally, the numerous and enjoyable discussions with my department colleagues Professor Anita Cerić and Professor Ivica Završki provided me with inspiration and persistence in my research plans. Of course, a number of other people also contributed to this thesis but the list would be too long to be included here. From this long list of contributors, I would like to mention the invaluable input from all the informants and organizations who participated in this research and chose to remain anonymous.

And finally, I am most grateful to my grandparents, mom, friends, and relatives who all remained confident that I would finish this research even in times when I myself was having doubts.

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# CHAPTER 1:
# INTRODUCTION

**Abstract:**

The aim of the first chapter is to provide the reader with an introductory tour of the practical and theoretical field that this thesis will investigate. The chapter begins with explicating the basic definitions of design and design management. Chapter 1 continues with addressing the issues of wicked problems, as well as hard and soft issues that distinguish design as a cognitive activity from production as a physical activity. By building on the basic definitions previously-introduced, I then elaborate the issues of design decomposition and integration as the main purpose of design management. Chapter 1 then explicates the research questions of this thesis and elaborates the general layout of the study before introducing the research methodology used to investigate the research questions. The chapter concludes with a list of broad issues that this thesis will address in its following chapters.

## *1.1 **Introduction***

A number of ingenious human inventions came into being as a sudden "spur of the moment" in the inventor's mind. We can find examples of such works not only in the domain of artistic expression, but also in the domain of technical systems. Such inventions, however, comprise in simple systems that are intuitively-understandable, such as the wheel or fire. Nonetheless, more complex artifacts that the human kind is collectively proud of are a result of long and laborious mental work, formally known under the term of *design*. Certainly, everyone reading this thesis already encountered an endless number of similar stories that glorify the human activity of designing in a number of knowledge fields. Following such a vague introductory paragraph the reader will naturally ask herself a host of questions: What is design anyway? What makes, for instance, spur-of-the-moment type of designs different from laborious ones? Is there such a thing as a general design philosophy, a common denominator covering various types of design activity? This chapter aims to give an answer to those and other questions, in an attempt to gradually set the stage for the core subject of this thesis: design of the built environment. The chapter begins with a general overview on design terminology, methodology, and attempt to assemble taxonomy of topics that the rest of this thesis will use subsequently.

## *1.2 **Basic Definitions***

### *1.2.1 Design and Design Management*

> *"Engineering, medicine, business, architecture and painting are concerned not with the necessary but with the contingent - not with how things are but with how they might be - in short, with design." (Simon 1996/1969)*

In the first edition of *The Sciences of the Artificial*, published in 1969, Herbert Simon introduced the concept of design as meta-knowledge in every profession. Traditionally, design has been considered as artistry pertinent to specific professions such as, for example, fashion, architecture, or even crafts of different kinds. In an artistic representation of design, however, very little room is left for a constructive and critical discourse that is necessary in every analytical activity. Nonetheless, this is not to say that a creative activity is a one-of-a-kind task with purely emotional value and, at the same time, without any realistic context and a rational basis for discussion. On the contrary, besides their symbolic value, most products also need to perform certain functions. As a consequence of the 1960s' urge of the human kind to rethink the fundamental concepts in an entire range of human activity, a new branch of philosophy emerged discussing design. In turn, the new fields called design science and design method began developing.

The design stream of literature is consistent in that there is a knowledge area missing between natural sciences, on the one hand, and social sciences and humanities, on the other. The science of the artificial is, therefore, needed (Simon 1996/1969). More recently, Cross (2007) summarized this very specifically:

> *"If we contrast the sciences, the humanities, and design under each aspect, we may become clearer of what we mean by design, and what is particular to it. The phenomenon of study in each culture is:*
>
> - *in the sciences: the natural world*
> - *in the humanities: human experience*
> - *in design: the artificial world*
>
> *The appropriate methods in each culture are:*
>
> - *in the sciences: controlled experiment, classification, analysis*
> - *in the humanities: analogy, metaphor, evaluation*
> - *in design: modeling, pattern-formation, synthesis*
>
> *The values of each culture are*
>
> - *in the sciences: objectivity, rationality, neutrality, and a concern for 'truth'*
> - *in the humanities: subjectivity, imagination, commitment, and a concern for 'justice'*
> - *in design: practicality, ingenuity, empathy, and a concern for 'appropriateness'"*

This thesis will elaborate a number of design features through an extensive literature review as well as empirical data presented in the following chapters. Although the reader will have a relatively complete picture of the term design by the end of this thesis, it would be beneficial to introduce a broad definition of design, as it is understood in this thesis, in advance.

**Design [as cognition]: The iterative loop of problem formulation, solving, and decision-making that leads the designer from the initially-perceived design situation to the final solution of the problem.**

**Design [as object]: A coherent set of information about the object that will have come into existence as a result of the corresponding problem-formulation, solving and decision-making.**

**Design management: The process of decomposing and integrating individual sets of design information by using a management-based rationale.**

### *1.2.2 Wicked Problems, Soft, and Hard Issues*

At this point, it might be reasonable to reconsider the purpose of the design process. Most certainly, it is to construct useful artifacts that will meet the needs of its users. Nonetheless, a universal and trans-disciplinary definition of design is still missing. Overall, this thesis argues for design as a planning process. At the front end of the design process is, therefore, a set of requirements, which should be embodied through the activity of design. On the back end of the design is the production process that will eventually turn the artifact into existence. The designer's position is in between the project requirements and the actual production process. In spite of this intermediary position, the transitional phase of decision making that we call design has the power to determine the faith of the product. For these reasons, **design is essentially a planning task**. It is about something to be created in the future.

Designing a new product (or artifact) with an engineering content is normally defined as the activity of producing information about the system that embodies the functions necessary for fulfilling the set of requirements set forth by the client (e.g., Pahl et al. 1996; Cross and Knovel 2000). In the case of facility design, these requirements need to be mutually negotiated between the stakeholders and the project coalition (Winch 2010). This significantly complicates the design decision-making process as interests of the client, the stakeholders, and the project coalition diverge. Additionally, the elicitation of requirements for the designed system is a tremendously challenging task because the requirements are often changing through time. For all these reasons, the process of designing construction is *ill-structured*. As Cross (1982) defined the general design discipline:

> *"Designers tackle 'ill-defined' problems, their mode of problem-solving is 'solution-focused', their mode of thinking is 'constructive', they use 'codes' that translate abstract requirements into concrete objects, they use these codes to both 'read' and 'write' in 'object languages'."*

The dichotomy between the *ill-structured* or *wicked* problems in contrast to *well-structured* or *tame* problems was first introduced by Rittel and Webber (1973) who argued that design problems are impossible to define and therefore no optimization in the traditional mathematical sense is possible for such problems. Some of the most obvious differences between tame and wicked problems are that the former are describable and determinate, whilst the in the latter, problem definition incorporates solution and only indeterminate solutions can be achieved (see, for instance, Winch 2010)

Wickedness and ill-structure have, to date, remained considered the fundamental property of design. In a more recent discussion about the subject, Coyne (2005) corroborates evidence for the ill-structured nature of design and extends the debate by stating that:

> *"Wickedness is the norm. It is tame formulations of professional analysis that stand out as a deviation."*

In contrast with the theoretical discussions about design, most known techniques used in design are by and large deterministic in that they disregard the wickedness of the design problem. In Coyne's terms, all of the available management methods give tame formulations of the wicked problem and, therefore, have a limited value. Table 1 below gives an overview of differences between tame and wicked problems (Winch 2010).

| *Tame problems* | *Wicked problems* |
|---|---|
| Solution set describable | Problem definition incorporates solution |
| Determinate solutions | Indeterminate solutions |
| Optimized solutions | Satisfied solutions |
| True solutions | Good solutions |
| Solution achievement definable | Solution can always be improved |

**Table 1: The difference between tame and wicked problems in design**

Another differentiation that this thesis will use is the one between hard and soft issues. I will here consider the issue of wickedness as the lack of understanding of a how a particular concept works. A more detailed analysis of the subject matter will oftentimes reveal simple principles of how something works. Other times, however, the system will behave in such a chaotic way that will disable the designer to predict its behavior. It is precisely to the distinction between these issues that this thesis is dedicated. I follow with this distinction between **hard and soft issues** in design that I will follow throughout the chapters of the thesis.

**Hard issues** might be complex, but they do not exceed the cognitive and information processing capacities of their solver (i.e. designer). Soft issues, by contrast are such that they exceed the limits of their solvers cognitive capacities. **Soft issues** are, therefore, unpredictable and incomprehensible aspects of designing. **Addressing both the hard and the soft issues constitutes a theoretical paradox in design**. At the practical level, it is what distinguishes good designers from poor ones.

*1.2.3 Design Management as Decomposition and Integration*

After defining the basic characteristics of design and the concept of the wicked, soft, and hard issues, it is time to introduce the issues of design decomposition and integration that sets the main focus of this thesis. The main purpose of design management is to coordinate and mutually align different components of design as a cognitive activity. The overall design is produced by a loose coalition of people with, not only diverse mindsets and disciplinary narratives, but often also with conflicting interests. Integration, therefore, becomes the key management issue in design. As Dorst (1997) described it:

> *"Someone is designing in an integrated manner when he/she displays a reasoning process building up a network of decisions concerning a topic (part of the problem or solution), while taking account of different contexts (distinct ways of looking at the problem or solution)"*

The importance of design decomposition and integration simply cannot be overstated as the final design solution of any product becomes meaningful only when different design components have been appropriately integrated with each other. In such a way, it becomes obvious that problems of design management can be reduced to the issue of design decomposition and integration with the information produced in different project phases and by different disciplinary actors. Integration within design occurs at multiple organizational levels from the micro-level of the design task to the macro-level of the design project organization. **Decomposition and integration are, therefore, the main purposes of design management.**

In this integration, the scope relative positioning of design issues within the overall context of the project is shown in Figure 1. The figure depicts the relative positioning and importance of design decision making in terms of the production processes.

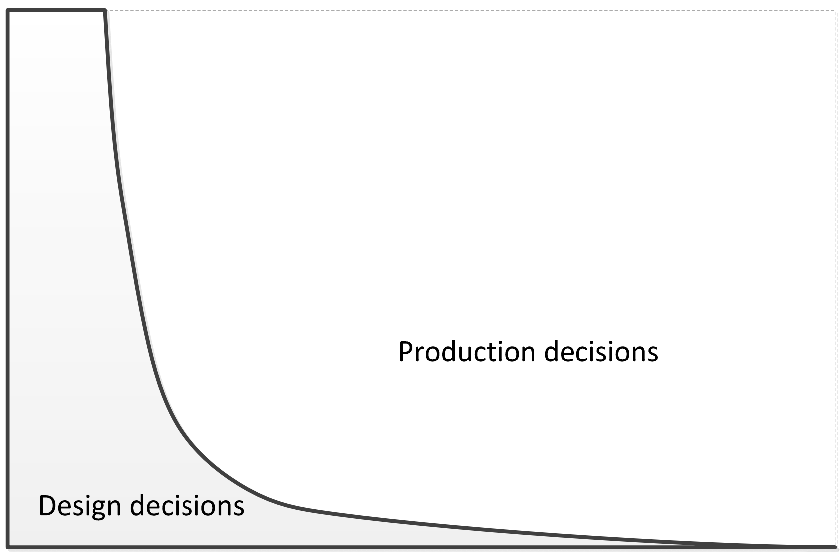


Figure 1: The relative positioning of design within the overall project decision-making

The integration of design therefore takes place in two main areas:

- Within design itself
- At the interface between design and the production processes.

### *1.3 Research Questions and Outline of the Study*

Following the above introduced properties, which distinguish design as cognitive activity from construction as physical activity, this thesis recognizes the **lack of knowledge and skills to manage design in the built environment**. In its development, the body of knowledge on design management should acknowledge design in the built environment as a distinct domain. This path of reasoning is not unlike the distinction between construction and other production sectors, the logic that led to the development of construction management as a theoretical domain in the 1940s. Therefore, the main goal of this thesis is to come one step closer to answering the following research question:

| |
|---|
| **Why concepts from production project management do not work for managing multidisciplinary design in the built environment?** |

In an attempt to chart a rough map of this immense field of inquiry, this thesis chose to subdivide the main research question into the process-level of design decomposition and project-level of design integration. This results in the following two sub-questions:

1. **What are the process-level properties of design that determine its decomposition?**
2. **What are the project-level properties of design that determine its integration?**

Although a number of theories provide partial explanations of the above posed problems, this thesis uses a theoretical approach of combining two broad fields of knowledge to explain the problem. The aim of using these theories was to approach the problem at its fundamental level as a basis for future research. The two theoretical fields that this thesis is based upon are design methodology and organization theory.

The next figure depicts the outline of this thesis (Fig 2). The "big idea" of the study is to analyze the mismatch between the project management theories and the nature of design management within the built environment in an endeavor to contribute to design management theory development. Design management is, for this purpose, viewed through the lens of design decomposition and integration that this study analyzes at the process- and project-levels.

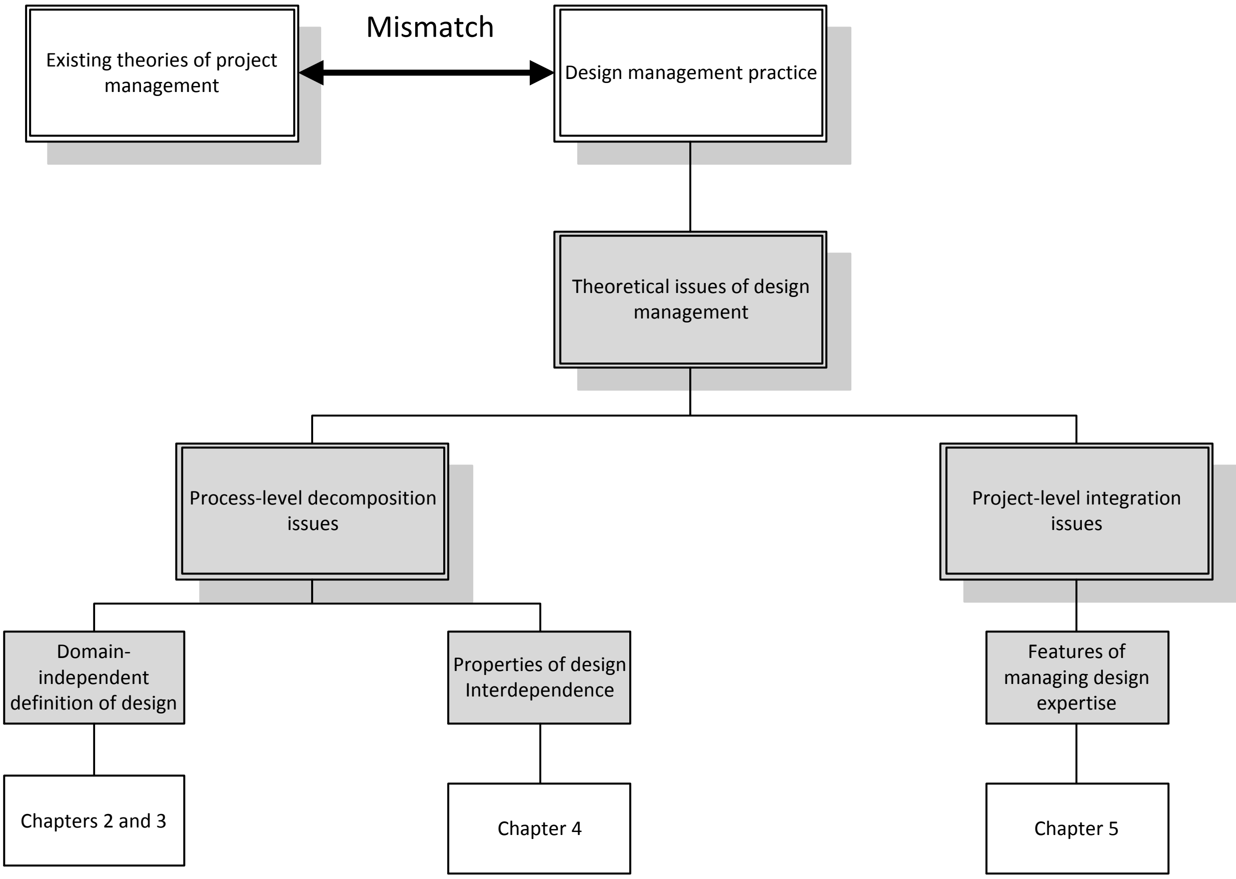


Figure 2: Conceptual overview of research questions and layout of the study

The process-level of design management that defines issues in design decomposition is a result of how design is defined in a domain-independent concept as well as the interdependence properties in design. Chapters 2 and 3 of this thesis are dedicated to the former and Chapter 4 to the latter. At the integration level of design management, this thesis will investigate the issue of design expertise and its management at the project-level of design. This is the main topic of Chapter 5 in this thesis. The thesis is, therefore, structured as follows:

Chapter 2 presents a summarized literature review of general design theory. The literature review revisits the philosophical paradigms of design thinking grouped into the categories of rational problem-solving and reflection in action. The theoretical representation of design is therefore bipolar and this is the main problem for implementing a consistent management theory into the field of multidisciplinary design.

Chapter 3 draws from findings in Chapter 2 to transpose general design theory into the field of the built environment design and presents a body of design management methodology that is used in the built environment. By summarizing the most promising methods to advance design management in the built environment, Chapter 3 sets the stage for the development of a domain-independent design management approach.

Chapter 4 derives a theoretical framework for process-level design management based on categories of design interdependence and validates it with an in-depth case analysis. This chapter derives its findings as a retrospective single case study of a major railway design and build project.

Chapter 5 continues by using the process-level characteristics of design interdependence to derive a theoretical framework for project-level design management that uses a novel conceptualization of design as a stream of knowledge transactions. The theoretical framework is validated with interview data and an anecdotal example from the case study. To derive the theoretical framework, Chapter 5 draws from a literature review in the field of macro-level neo-institutional theories of sociology and economics.

Chapter 6 gives conclusions, summarizes the contributions and references used throughout the thesis.

The next section describes the research methodology in this thesis. Not unlike the endeavor of design itself, this thesis uses an iterative and non-linear methodology to develop the theoretical findings.

## *1.4 Research Methodology*

"*Basic research involves a search for general principles. These principles are abstracted and generalized to cover a variety of situations and cases. Basic research generates theory on several levels. This may involve macro level theories covering wide areas or fields, midlevel theories covering specific ranges of issues or micro level theories focused on narrow questions. General principles often have broad application beyond their field of origin, and their generative nature sometimes gives them surprising power.*

*Applied research adapts the findings of basic research to classes of problems. It may also involve developing and testing theories for these classes of problems. Applied research tends to be midlevel or micro level research. At the same time, applied research may develop or generate questions that become the subject of basic research.*

*Clinical research involves specific cases. Clinical research applies the findings of basic research and applied research to specific situations. It may also generate and test new questions, and it may test the findings of basic and applied research in a clinical situation. Clinical research may also develop or generate questions that become the subject of basic research or applied research."*

This is how Friedman (2003), in a discussion on design research, classified categories of knowledge generation in design. As in most other fields of inquiry, the knowledge generation can proceed in either deductive or inductive directions. In deductive reasoning, the knowledge cycle begins with basic research that subsequently applies universal principles to classes of problems and specific cases. Inductive reasoning, by contrast, works in the opposite direction, in which theory is built by generalizing empirical findings from particular cases to more general problem sets.

Multidisciplinary design of the built environment contains both approaches: inductive reasoning in the conceptual design of architecture, which creates the shape and content of the structure, and deductive reasoning in the engineering part that applies universal scientific principles to the given structural concept.

Design literature has long acknowledged the need to devise research methods that match the properties of the field more appropriately than commonly-used research approach in management literature. Following advice from the general design research theory, a summary of shortcomings in the existing research approaches are:

- The deductive hypothesis-testing is inappropriate for design research because of lack of literature on subject matter. Due to its craft tradition, most design and new product development is based on tacit knowledge (Friedman 2003).

- The inductive theory building tends to yield theoretical frameworks that are "very rich in detail but lack the simplicity of overall perspective" (Eisenhardt 1989).

Given the craft tradition of multidisciplinary design, where most reasoning is case-based, or clinical, the deductive hypothesis testing was not an option due to the fact that there was no opportunity to develop the hypothesis from an existing body of knowledge. Instead, this research employed iterative cycles of grounded theory building to develop the hypothesis and test it subsequently. It is a two-phase approach that corresponds to the research focus of process- and project-level issues in design management.

### *1.4.1 Exploratory Study*

The first phase of this research included an exploratory study by collecting diverse data from six multinational design organizations as a set of case studies. The sample consisted in a population of multinational construction design and engineering organizations. The logic of the sampling strategy was to reduce variation due to size and regional focus, thereby setting the domain of the findings to large multinational design and engineering organizations. Six cases were selected based on market sectors of the organizations' core specialty. Those market sectors are:

- Engineering design of buildings and public infrastructure (3 cases)
- Integrated real estate development, design, engineering, and project management services (1 case)

- Engineering, procurement, and construction of oil, gas and petrochemical facilities (1 case)
- Interior design and architecture (1 case)

The exploratory phase was based on open-ended ethnographic interviews with informants with practical design management experience. Each interview lasted for 60 minutes and was organized, as appropriate, either as a personal meeting, or a telephone conversation. The interviews were audio-recorded and transcribed subsequently.

The result of the first phase of research was an exploratory analysis on the **project-level issues of design management that form the basis of reasoning in Chapter 5**.

*1.4.2 Case Study*

In the second phase of this research, I conducted an in-depth case study to further corroborate findings from the company-level data as well as to gather rich data from a multi-organizational project setting. Following Yin's (2003) advice, I chose a project that represents a *critical case* and encapsulates a wide range of complexity issues that I aimed to chart and generalize from. To accomplish this, I researched a major public-funded railway engineering design-build project in a major European city where I interviewed design managers with the aim to uncover the managerial sensemaking process retrospectively, by having all the relevant data after the project had finished (Weick et al. 2009; Winch and Maytorena 2009). The described research design, I believe, enabled me to complement the breadth of generalizeability in the exploratory approach with the detail of a single case study. The case study is retrospective because the decisions that affected the project events can, in such cases, only be evaluated *ex post*. I, therefore, chose to trace the processes resulting from decisions in a fast-paced and complex design-build railway engineering project. In a retrospective process-tracing setting, I hoped to encapsulate the uncertainty and the process flow that would have not been possible to address with ongoing project events.

The case study uses a data collection method that combines process-tracing through cognitive mapping on a retrospective case study to capture the sensemaking processes in complex design situations. Instead of using the standardized protocols with a single interpretation of the data collected, this research collected data in a manner that supports the cognitive and interpretive nature of design. This is done through the open ended interviews that opened the possibility of different interpretations based on the informants' sensemaking of the subject matter. When combined with secondary and tertiary sources of data, the overall data collection was immensely rich and required a thorough coding that revealed the complexity and non-linearity of design. The research method chosen, therefore, produces the iterative loop of qualitative theory building and hypothesis testing, very similar to the process of design itself (Eisenhardt 1989; Friedman 2003).

The result of the second phase of this research is the in-depth analysis of the **process-level issues of design management that form the basis of reasoning in Chapter 4.**

Theory-building in this thesis is presented in an opposite direction from data collection. More specifically, the thesis first presents process-level findings on characteristics of design and then elaborates the management component on the project-level design. I believe that this is the most logical direction of presenting the study.

## *1.5 Summary*

The first chapter attempted to provide a rough "map" for the theoretical territory that this thesis will investigate. The aim of the chapter was to introduce the basic issues of design management along with several characteristics that make it complex and subject to analysis:

- Interdependence between sub-tasks: Parts of the design decision making process cannot exist in isolation, they are reciprocally interdependent in that one task cannot be altered without the need to alter all the other (e.g., Thompson 2003).
- Uncertainty: Because information about the project is *under social construction*, there is an inherent lack of information that would be needed to reach a decision unambiguously.
- Wickedness: Wicked or ill-structured problems, as opposed to tame problems, are such that their complete formulation is not possible (e.g., Rittel 1977). All design problems are essentially wicked problems which makes them inappropriate for traditional mathematical optimization methods.

- As a result of these characteristics, the main issue of design management is decomposition and subsequent integration of its components, which this study will use as a practical research focus.

I believe that providing such a broad-brush and a somewhat kaleidoscopic, introductory "tour" of the topic also reflects the theoretical pluralism of design research that the forthcoming chapters of this thesis will address. Since the object under study is still relatively unexplored, the findings in this thesis are of descriptive nature and their development into a normative model that can be readily used in the design practice still requires substantial work. Even more work is ahead to develop a predictive model from its normative form. Despite the descriptive nature of the current framework, this thesis develops an initial set of recommendations that design managers will find useful for improving processes in their projects.

# CHAPTER 2:
# THEORETICAL PERSPECTIVES ON DESIGN

**Abstract:**

Whereas Chapter 1 introduced the research topic and gave a broad-brush introduction into the need to research the field of design management, Chapter 2 of the thesis aims to provide a comprehensive **overview of design theory**, with an emphasis on its development and different theoretical representations. Departing from the philosophical basis of reasoning in the natural and social sciences, this part of the thesis elaborates the two theoretical streams that describe design in a **problem-solving and action-centric manner**. The two separate representations of design have found their applications in different domains of human activity, which complement each other in the design processes. The result is a **bipolar theoretical representation** of design with consequences for its management, as the next chapters will demonstrate.

## 2.1 INTRODUCTION

There has been an ongoing debate about defining design in terms of new product development. In the realm of industry and engineering, design has been considered in terms of utilizing technical expertise to plan various aspects of new products (see, for example, Pahl et al. 1996). New product development, by contrast, is a much broader term, encompassing not only the technical aspects but also strategic business and planning aspects of a new product (e.g. Cross and Knovel 2000). In academic discussions, the field of design is substantially represented in interdisciplinary journals such as, for example, *Design Issues, Design Studies, Journal of Engineering Design,* and *Research in Engineering Design,* which this thesis all uses as the main sources of theory in domain-independent design research. Otherwise, major research areas in the field of design are published in peer-reviewed scholarly journals that represent different disciplines.

After having briefly introduced the building blocks for the subsequent theoretical discussion in this thesis, it is time to introduce the philosophical basis of design thinking. By now, it is already clear that design as a human activity is substantially different from production-based activity that most of organizational literature has been dealing with.

This chapter will elaborate the most prominent streams of literature covering design as an object of academic inquiry. First, the chapter will attempt to disentangle the philosophical basis of the available theory and methodology and, attempt to categorize knowledge in distinct streams of thinking. And finally, this chapter will elaborate the design theory in the built environment and, by showing the relation to previously introduced general theory, establish the need for a domain-independent approach to design in the built environment.

## 2.2 THE DEVELOPMENT AND STRUCTURE OF DESIGN THEORY

### *2.2.1 __Design Theory Development__*

The roots of design theory can be traced back to the 19th century German school of industrial engineering and engineering design. Some of the most notable developments in the field occurred through the application of mathematics into the field of industrial production. Such is, for instance, the area of operations research, which came into existence as a response to optimize the industrial processes of production that developed through most of the 19th and 20th century. The developments of operations research were significantly intensified as a result of the World War II and various governments' efforts to use applied mathematics to track bombs and submarines. Likewise, a plethora of decision making techniques emerged from the area of applied mathematics[1].

The basic scientific description of domain-independent design comes from Herbert Simon who in many ways paved the way to the science, methodology and management of design, as we know it today. His pioneering works gave a descriptive and generalized overview on the design process as meta-knowledge of all human professions. Thus, the notion of design science, as a rational description of the processes that occur in design, became feasible. The positivist school of design research established the foundation for scientific and analytical approaches to design, by proposing that design can, in fact, be researched as a structured activity.

Simon, however, also emphasized the limits of the thinking power that the decision makers exhibit. This is captured in what is today regarded as *the concept of bounded rationality,* a realization that places all the modeling concepts into a relative framework. The first instance when bounded rationality was used in the planning and design terminology is the following one (Simon 1955):

> *"Traditional economic theory postulates an "economic man," who, in the course of being "economic" is also "rational." This man is assumed to have knowledge of the relevant aspects of his environment which, if not absolutely complete, is at least impressively clear and voluminous. He is assumed also to have a well-organized*

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[1] A comprehensive review of the history of design research is available in Bayazit (2004)

> *and stable system of preferences, and a skill in computation that enables him to calculate, for the alternative courses of action that are available to him, which of these will permit him to reach the highest attainable point on his preference scale."*

Simon, therefore, also indicated that the concept of bounded rationality to a certain extent opposes the structured problem-solving and decision-making paradigm. According to Simon, decision making is an intendedly-rational process, but only limitedly so. At the level of an individual, a large number of decisions are made in an ad-hoc manner under conditions of uncertainty and the decisions are only assigned their final meaning retrospectively.

This notion has been only partially taken into account by various methods that use structured parameters to represent the uncertainty aspects in the existing structure of the models. The most notable field of such techniques is termed decision-making under uncertainty with the representatives of decision trees, analytic hierarchy process, and the like. However, many argue, this still does not address the problem of bounded rationality in an appropriate manner.

The problem here is that cognitive limits of bounded rationality have the power to change the structure that might have been envisaged through the existing design methods. The debate on the inappropriateness of the existing methods used in design has been intensifying particularly since the 1980s. As a response, a new theoretical stream began evolving in design, based on the constructivist philosophical view on the world. Currently, academic journals more inclined towards the arts and humanities are dealing with the constructivist stream of research of design cognition. The philosophical bases that support the constructivist paradigm are phenomenology, which concerns the study of human subjective experience, and the theory on the social construction of reality. The constructivist approach is also typical as a post-modern interpretation of reality where relativism and pluralism precedes a universal set of values.

As opposed to the positivist reasoning, the constructivist paradigm of design acknowledges that design is both an individual and collaborative effort by human designers with personality traits. As such, it is a socially constructed object that is not always suitable for methodological approaches. Proponents of the constructivist design paradigm, in fact, claim that in many cases the creative process, taking place during design, cannot be represented in any meaningful way at all. Instead, they propose a different conceptualization of design: one where artifacts are conceived as an interaction between the human designers and the their work in progress (Schön 1983). The point of departure for the cognition stream is the notion that the individual designer is only capable to tackle the design task from his/her personal perspective, also called *the design situation*.

As a result of the historical developments, two theoretical streams exist that describe the activity of design. Both streams have their advantages and shortcomings as they both describe design to a certain extent. The existing theory, therefore, considers them as two aspects of design description that should be taken into account simultaneously, rather than exclusively. How to achieve this unification at the theoretical level, however, still remains unclear.  As a consequence, this is projected into the field of design methods that still largely rely on the "hard" concepts and by and large disregard the "soft" aspects of interaction and reflection.

### *2.2.2 Structure of Design Knowledge*

The above-introduced development of general design theory can be grouped into specific fields based on the nature of the corresponding theoretical and practical contributions. As Birkhofer (2011) argues, design and new product development are increasingly being equated as terms in contemporary design methods literature as the design field continues to move beyond classical engineering. The broad area of design knowledge can be formally categorized into, for example, design science and methodology (Birkhofer 2011, p.11):

> *"In the Design Methodology and Technology area knowledge is extracted from the analysis of observed phenomena of design practice. Additionally, the knowledge is conditioned and documented in a database. Based upon this, strategies, methods and tools are generated. This area of activity is the characterized by abstraction and modeling and by formulating prescriptive proposals for better products and design processes. Here, goals are the efficiency of access to knowledge and the manageability and level of support of the methods in specific development scenarios. The conditioning of results is a form of applied science. It uses the*

*results and findings of design science to achieve scientifically substantiated support for design practice that has a certain entitlement to universality.*

*Finally, in the Design Science area, observed phenomena are traced back to generally admitted, scientifically accepted fundamentals by generalization. Working in this area leads to theories, axioms, and paradigms that describe findings on the real world of design in a compressed and highly abstracted form. Thus, criteria such as truth, logic and correctness are paramount.“*

It becomes clear that areas of design science and methodology are mutually interdependent and the development of one knowledge area leads to advances in the other in a constant interplay between the descriptive and normative representation of knowledge. A more applicative definition of design methodology, than the one described, is proposed by Pahl et al. (1996) and this will be the grounding for the forthcoming theoretical discussion in this thesis.

*“Design Methodology is understood as a concrete course of action for the design of technical systems that derives its knowledge from design science and cognitive psychology, and from practical experience in different domains. It includes plans of action that link working steps and design phases according to content and organization. These plans must be adapted in a flexible manner to the specific task at hand. It also includes strategies, rules and principles to achieve general and specific goals as well as methods to solve individual design problems or partial tasks.”*

## 2.3 DISINTEGRATION IN DESIGN THINKING

Overall, design theory has been developing in several separate directions with very little overlapping. This thesis will elaborate streams of design theory based on the two philosophical paradigms that belong to the professional camps of engineers and architects/industrial designers, who have been acknowledged as leaders of the design field from within their own perspectives. Roozenburg and Cross (1991) seem to have been the first to formally acknowledge the disparity in the existing views. While the majority of engineering literature conceptualizes design as a systematic sequence of tasks, the architectural and industrial engineering literature views design as ill-structured, without the realistic possibility to determine the structure or process of the effort.

Quite similarly to the previous discussion, Dorst and Dijkhuis (1995) subsequently condensed design thinking into two distinct schools of thought: *design as rational problem-solving and design as reflection-in-action*. The paradigm of design as rational problem solving emerged from theories on technical systems and, in particular, Simon's (1955) behavioral theory of human rational choice. In this conceptualization, albeit they are ill-structured, design problems exist and are solvable by using the designer's rational mindset. The reflection-in-action paradigm, by contrast, represents an entirely different mindset. It is one where design is seen as a reflective process of the designer interacting with the design product. The fundamentals of this theory have been firstly put forth by Schön (1983) and continue to be of centrality for design research ever since.

Due to this notion, a new nomenclature was introduced that begun differentiating between hard and soft systems paradigms. Winch (2010) summarizes this dichotomy with *hard* systems consisting in well-structured or tame problems that are easily defined and described, they have determinate solutions, and thus can be optimized. Elements in hard systems are considered ontological[2] entities that can be explained and structured objectively. Soft systems, by contrast, consist of ill-structured problems that are not definable in that a problem formulation also incorporates a solution. Solutions to such problems are thus indeterminate and not susceptible to mathematical techniques of

[2] An ontological system is one that exists irrespective of the mental interpretation of its observer and as such is an object of objectivistic research paradigm.

optimization (Rittel 1977). Systems conceptualized in this vein are soft, in that they are epistemological entities[3] that only exist as their observers' mental interpretation

The entire field of design theory can therefore be grouped advantageously into the areas of ***hard*** and ***soft systems***. In this thesis I continue along the lines of this categorization as the former is a representative of the positivist and the latter of the constructivist scientific paradigm, which makes the differences in the corresponding narratives easier to interpret.

| *Stream of Design Theory:* | *Problem-solving* | *Action-centric* |
|---|---|---|
| The nature of system | Technical, Physical | Social, Psychological, Cultural |
| Philosophy and theoretical basis | Positivism, objectivity, rational choice theory. | Constructivism, interpretation, social construction of reality |
| Principles | The principle of near-decomposability and linear superposition of independent components. | The principle of interdependence, properties are emergent at different analytical levels. |
| Assumptions | The nature of the problem is tame. The system can be approximated as linear. | The nature of the problem is wicked. The system is non-linear. |
| Cognitive mode | Deterministic planning under bounded rationality. Plan-driven information processing | Sensemaking and enactment under fuzzy circumstances. Creativity- and emotions-driven improvisation. |
| Basis for management methodology | Hierarchical decomposition, systems engineering toolbox | Systems thinking, agile methods toolbox |

[3] As opposed to the definition of ontological entities, epistemological systems exist only in the context of their observers' cognitive processes, therefore, they can be considered as objects of the interpretative stream of research.

| | | |
|---|---|---|
| Domain-independent representatives | (Hubka and Eder 1987; Pahl et al. 1996; Simon 1996/1969) | (Cross 1982; Schön 1983; Dorst and Cross 2001; Bucciarelli 2002) |

Table 2: An overview of design theory streams

Since the 1960s, researchers and the wider community have acknowledged that the hierarchical decomposition reasoning only applies to the case of well-structured problems and that it does not necessarily apply to real-world situations that are, as a rule, ill-structured. This marked the beginning of the debate on soft systems and as yet another application of the constructivist paradigm into design practice. In this debate, soft systems are defined with their ill structure.

The soft vs. hard systems discussion is in management literature often complemented with the dichotomy of decision-making under risk vs. uncertainty. The former is characterized with a possibility of assigning a statistical distribution of occurrence to any one event that might cause an adverse impact on the project. The latter category, on the other hand, defines events that are impossible to assign a statistical value of occurrence for a number of reasons. De Meyer et al. (2002), for instance, classified levels of uncertainty on projects into the categories of variation, foreseen uncertainty, unforeseen uncertainty, and chaos. These uncertainty categories encompass a range of decision making modes, from simple and statistically quantifiable, to iterative problem solving in chaotic circumstances of sensitive dependence on initial conditions where the slightest change in the system might produce massive consequences for the entire system (Thietart and Forgues 1995).

The present section will elaborate the main features of the two parallel, but oftentimes confronting worlds, within which design is discussed as an area of inquiry. Based on this elaboration, I will offer a conceptual model that integrates the two paradigms of design theorizing.

## 2.4 DESIGN AS LINEAR PROBLEM-SOLVING

This perspective conceptualizes design as rational problem-solving in a **well-defined technical and physical system**. The underlying philosophical basis for this approach is analytical reductionism, and the assumption of system near decomposability. The theory on systematic design is a representative of the problem-solving approach, and, consequently, the entire field of design methods emerged from this view.

### *2.4.1 The Underlying Philosophy*

The concept of design as a technical system is based on analytical reductionism, a philosophical position that a complex system is a sum of its parts and the behavior of a complex system can be reduced to the behavior of its individual constituents. The principle of superposition is the main principle that analytical reductionism uses in its explanations of the natural phenomena. The paradigm of analytical reductionism dominates a number of scientific areas in basic science (i.e. physics chemistry, cell biology), and applied science, in particular, classical mechanics as the basics of engineering. Although the narratives of reductionist engineering theories acknowledge that the principle of superposition is only an approximation, they are used due to the lack of methods that would take into account the non-linear aspects of engineered systems. The assumption of the technical stream in design theory is that the complex system is decomposable into discrete units that make in a hierarchical order. The basis of the hierarchical order is the concept of near decomposability defined by Herbert Simon (2002) as:

> *"At any level of the hierarchy, the rates of interaction within components at that level are much higher than the rates of interaction between different components. Systems with this property are called nearly completely decomposable, or more briefly, nearly decomposable"*

### *2.4.2 Theory of Systematic Design*

The dominant stream of literature in new product development and engineering design area of inquiry deals with the overall features technical systems and organizes the design process accordingly. As a continuing stream of research on technical systems that was pioneered by Hubka and Eder (1987), Pahl et al. (1996), for example, advanced the field by dividing the product development process into the following phases:

- Planning and task clarification: specification of information. This working step results in the list of requirements, which the final product should conform to.
- Conceptual design: specification of principle solution. This results in a conceptual solution represented in an abstract form such as functional diagrams, flowcharts, or even sketches.
- Embodiment design: specification of layout. This working step specifies the overall layout of the designed technical system.
- Detail design: specification of production. This working step specifies all the details as required for the production process.

This division is clearly based on the engineering design process conceptualized as rational problem-solving. Furthermore, it is an example of a functional notion of design. In this notion, the overall aim of the design process is to invent systems that perform functions formulated from the client's requirement specifications. These functions are formulated in a noun-verb form such as, for instance, *transfer torque*. The designer subsequently forms a systematic structure of subsystems that deliver the needed functionality. This abstract structure is in the next working step elaborated down to the level of the system's embodiment that describes a more realistic representation of the technical system. Finally, the criteria of production are implemented into design system to provide for a constructible solution. Since this is a widely-accepted description of the design structure and process, I shall extract the two basic features of this representation. They are:

- The structure of design is hierarchical as it consists in a number of subsystems whose interdependence is easily modeled.

- The process of design is structured according to the components of the hierarchy and their mutual temporal interdependence.

When these two definitions are adopted, it follows that if a designer follows the structured series of steps in the process, the result will be the designed product, according to the hierarchy of system-level components. A number of design tools emerged from the systematic description to facilitate and, to a certain extent, even standardize the design process.

### *2.4.3 Design Methods*

In a well-elaborated piece describing design as a cognitive activity, Henrik Gedenryd (1998) defines design methods as follows:

> *"A design method is a normative scheme that specifies in detail a certain working procedure, the activities to perform, and also a specific order in which the activities should be carried out. It is usually very precise, and the designer is to follow it meticulously. It also covers the design process from beginning to end.*"

One of the first sources that cover the design methodology camp is Christopher Alexander's Notes on the Synthesis of Form (1964). As Purgathofer (2006) summarized the original Alexander's contribution:

> *"In Alexander's work, the influence of the subjective designer is replaced by a systematic model of the design process. It divides the design process into analysis and synthesis, whereby both phases can be executed (quasi-) automatically on the basis of hierarchical decomposition…*
>
> *…In this we can also find one of the motives for the attempt to make the design process more scientific through the definition of more rigid, rational methods. The principles of science—repeatability, transparence and provability— are to become applicable by minimizing or removing the individual, subjective and ''irrational'' influence of the designer. For this it is necessary to represent this influence as one which should be rejected. Alexander does this by talking about the ''especially proper decomposition'' for a problem, indicating that it could be objectively correct, which also means that it is implicitly better than a designer could ever make it."*

Later, however, the entire argument was abolished by Alexander himself in a very decisive manner, as, in his opinion, prescriptive design methods have very little to say about the reality of designing buildings.

According to Gedenryd, (1998) design methods consider design a problem-solving activity and disregard its interactive learning aspects. Along these lines, several principles unify the available hard design methodology (Gedenryd 1998):

1. *"Separation: The separation of the design process into distinct phases, with each individual activity being performed in isolation from the others.*
2. *Logical order: The specification of an explicit order in which to perform these different activities.*
3. *Planning: The pre-specification of an order in which to perform the activities within a phase.*
4. *Product-process symmetry: The plan being organized so as to make the structure of the design process reflects the structure of the sub-components of the resulting design product."*

The above-mentioned four unifying principles of design methods also imply the separation of analysis and synthesis as cognitive processes. In other words, analysis of the problem precedes its solving (synthesis). Iteration is included in such models only as a loop of the same working procedure.

## 2.5 DESIGN AS INTERACTIVE INQUIRY

The interactive inquiry perspective conceptualizes design as behavior of a **social, psychological and cultural system.** The underlying philosophical basis for this approach is social constructivism and the sensemaking concept in erratic situations. The action-centric theory of design is a representative of this approach and systems thinking can be considered as an attempt to bring this concept into the camp of design methodology.

### *2.5.1 The Underlying Philosophy*

The constructivist philosophical paradigm acknowledges that most decisions are influenced by the social context that the individual decision-maker finds himself/herself in. In such a collective action, therefore, meanings are not only a product of one's own perception of the situation, but rather a result of an explicit or implicit process of social negotiation. Socially-negotiated actions adhere to rules of social construction of reality where the knowledge is contingent upon the actors constructing it rather than any inherent quality that exists in its own right (Berger and Luckmann 2007/1966). The theoretical basis for conceptualizing design as a soft system is the social psychological model of *sensemaking and enactment*. Karl Weick is one of the pioneering scholars who have brought the concept of *sensemaking* into organizational studies with having in mind that meaning supersedes decision-making.

> *"One way to shift the focus from decision making to meaning is to look more closely at sensemaking in organization. The basic idea of sensemaking is that reality is an ongoing accomplishment that emerges from efforts to create order and make retrospective sense of what occurs."* - (Weick 1993)

In sociology literature, sensemaking is the process by which people define their experience by retrospectively assigning meaning to past events and thereby shaping the organizational context for present and future events. In his analysis of sensemaking in the 1949 Mann Gulch disaster where thirteen firefighters died, Weick (1993) argues:

> *"Sensemaking is about contextual rationality. It is built out of vague questions, muddy answers, and negotiated agreements that attempt to reduce confusion."*

As such, sensemaking is different from instantaneous cognition because, Weick et al. also argue, (2005) human action is always one step ahead of the current understanding of the situation. Or, put differently, *ex ante* and *ex post* interpretations of events will differ in most cases. Because of all the above reasons, interpretation should precede rational choice as a unit of analysis (Weick 1998). In close relation to the sensemaking concept is the process of enacted environments, which link action and sensemaking. Likewise, Weick (1988) studied this phenomenon and his comments about a general advice to take "an appropriate action" during a crisis situation are:

> *"People often don't know what the 'appropriate action' is until they take some action and see what happens. Thus, actions determine the situation. Furthermore, it is less often true that 'situations' determine appropriate action than that 'preconceptions' determine appropriate action. Finally, the judgment of appropriateness' is likely to be a motivated assessment constructed partially to validate earlier reasoning… Understanding is facilitated by action, but action affects events and can make things worse. Action during crisis is not just an issue of control, it is an epistemological issue. If action is a means to get feedback, learn, and build an understanding of unknown environments, then a reluctance to act could be associated with less understanding and more errors."*

This, once again clarifies the notion that human action and sensemaking are interwoven. It is, therefore, a theoretical support for Schön's reflection-in-action paradigm of designing that the previous section introduced.

### *2.5.2 The Concept of Action-Centric Design*

These shortcomings are taken into account when the design system is conceived as a social-psychological framework. A design situation is, therefore, an angle of perception from which the problem is approached. Since a number of conflicting perspectives on a single situation can exist, it can be said that designers are victims of their own perceptions of the design situation. To better illustrate the constructivist paradigm in design research, I adopt the widely established discussion in design research, which takes Schön's (1983) theory of design as reflection-in-action as the basis and the most appropriate representative of the constructivist thinking in design. The basis of Schön's theory is that the rational problem-solving paradigm in design neglects the importance of *problem setting* in design: The following passage best illustrates the core of Schön's reasoning (Schön 1983):

> *"In real-world practice, problems do not present themselves to the practitioner as givens. They must be constructed from the materials of problematic situations which are puzzling, troubling, and uncertain. In order to convert a problematic situation into a problem, a practitioner must do a certain kind of work. He must make sense of an uncertain situation that initially makes no sense. When professionals consider what road to build, for example, they deal usually with a complex and ill-defined situation, in which geographic, topological, financial, economic, and political issues are all mixed up together. Once they have somehow decided what road to build and go on to consider how best to build it, they may have a problem they can solve by the application of available techniques; but when the road they have built leads unexpectedly to the destruction of a neighborhood, they may find themselves again in a situation of uncertainty."*

More recently, in a comprehensive comparative study of the rational and reflective paradigms, Dorst and Dijkhuis (1995) contend that designers interact with their actions and thereby construct the design results:

> *"In this 'reflective conversation with the situation', designers work by naming the relevant factors in the situation, framing a problem in a certain way, making moves toward a solution and evaluating those moves."*

This situational approach could be the main reason why still a comparably-limited amount of articulated knowledge exists within the field of design. Design as a reflective activity is not so much prone to analysis and methodology-driven structure. Friedman (2003), for example, observed that:

> *"All knowledge, all science, all practice relies on a rich cycle of knowledge management that moves from tacit knowledge to explicit and back again. So far, design with its craft tradition has relied far more on tacit knowledge. It is now time to consider the explicit ways in which design theory can be built—and to recognize*

*that without a body of theory-based knowledge, the design profession will not be prepared to meet the challenges that face designers in today's complex world."*

The above-introduced elements of tacit knowledge and subjective experience introduce what would be considered a logical paradox in the systematic design paradigm. Dorst (2006) summarizes some of the paradox situations inherent to the experiential notion of design:

1. *"The "design problem" is not knowable at any specific point in the design process. With the adoption of the design situation as the unit of description, the question of defining the design problem as a whole becomes irrelevant. The paradox that drives the design process within a problematic situation, at a certain moment in the design process, should be determined from the designers' actions and words. The next task we then encounter in the quest to really understand design is, of course, to define the structure of the discourses. This could be difficult, although Foucault has developed some basic methodologies for this in his original work on the history of the discourse on mental illness.*
2. *The "design problem" is hard to identify because it evolves in the design process. This is partly covered above. We could add that the discourses hardly evolve within a design project, but that paradoxes (the point at which the discourses clash, and the way in which they do) may evolve throughout the design project.*
3. *The connotations of the very concepts that are used to describe a "design problem" are shifting as a part of the design effort. The central notions that make up the paradoxes the designers are dealing with indeed are meant to shift in the course of creating a solution. A clear view of the original discourses that play a part in the design project will provide an anchoring point for understanding these shifts."*

To solve such "problems", designers must work in a collaborative social setting with shared values, which creates the basis for the formation of culture. Bucciarelli is one of the researchers who strongly emphasize the cultural and collaborative aspects of design. Designers, therefore, work in a micro-cultural setting where they communicate across different object worlds. As Bucciarelli (2002) points out:

*„An object world is a world of a variety of things particular and specialized modes of representation. Object worlds have their own unique instruments, reference texts, prototypical bits of hardware, tools, suppliers' catalogues, codes and unwritten rules. There are exemplars, standard models of the way things work from the disciplinary perspective of the particular world and particular metaphors which enlighten and enliven the efforts of inhabitants. There are specialized computational methods, specialized ways of graphically representing states and processes. And participants work with a particular system of units and with variables of particular dimensions, certain ranges of values perhaps. Dynamic processes, if that is their concern, unfold with respect to a particular time scale – for someone's world it may be milliseconds, in another's, hours or days."*

It becomes clear that the designing environment is equally suitable for anthropological ethnographies of the design processes.

### *2.5.3 Methodological Implications: Systems Thinking*

The realization that real-world systems, especially ones comprising people, do not follow the linear hierarchical decomposition concept gave birth to various formulations of soft systems methods. The soft systems methodology, as firstly put forth by Checkland (1981), has been based on the notion that, in realistic problem situations, the definition of what consists a problem is not uniformly defined due to the number of participants in the problem. In this concept, soft systems differ from hard systems only in the perception of their observer. Whereas the in the "hard" paradigm the real world is perceived as a set of systems that can be engineered, in the "soft" paradigm, the reality is perceived as fuzzy and complex, therefore, the exploration of such a complex reality can be organized as a learning system (Checkland 2000). The difference here is, thus, whether the world or the process of learning about the world is perceived as systemic. Boardman and Sauser (2008) offered the following definition of systems thinking:

*"We believe, as do many others, that there is such a thing as systems thinking. This is not just thinking about systems – that would be enough, but, more interestingly for us, it is a thinking that is based on the notions or concepts that essentially define systems as phenomena. It is thinking from (or with) systems. The former has*

*systems on the outside, the object of our thinking. The latter has them as a wellspring of fresh thinking, of opposites and paradoxes, of simultaneously tenable viewpoints, a thinking that is "out of the box."*

Instead of trying to use a reductionist approach and decompose the problem, the systems thinker solves it by embracing the inescapable human condition of bounded rationality and uncertainty. This conceptualization is highly non-linear in that small changes can produce enormous effects on the entire system. In chaos theory, this phenomenon is known as the butterfly effect[4].

What this means in practice is that instead of perceiving the observed problematic situation as a structured system, the problem-solver approaches it by using a systematic learning process consisting in the following steps (Checkland 2000):

1. *"Finding out about a problem situation, including culturally/politically;*
2. *Formulating some relevant purposeful activity models;*
3. *Debating the situation, using the models, seeking from that debate both: changes which would improve the situation and are regarded as both desirable and (culturally) feasible, and the accommodations between conflicting interests which will enable action-to improve to be taken;*
4. *Taking action in the situation to bring about improvement."*

[4] This discussion adopted Gleick's (1987) commonly cited definition of chaotic behavior of systems.

## 2.6 TRANSITION TOWARDS DESIGN MANAGEMENT: PROCESS RESEARCH

There has been an ongoing research effort with the aim to identify processes in design that lead to successful realization of the desired outcome. The idea of the process view is that any effort can be divided into a sequence of distinct phases. Although any effort can be represented as a sequence of events, the value of the process view is in its descriptive and normative features. For that matter, descriptive process representations are also called *process maps*, and normative process representations *process protocols*[5].

### *2.6.1 The Iterative Process of Cognition and Information Exchange*

Due to the social-psychological features of design that cause its iterative and erratic nature, the value of phase-based process models is relatively limited, but there have been some valuable attempts to describe the design process. One of the more recent models of the design process is Gero's (2004) situated *Function, Behavior, Structure* (FBS) model with the following features:

- "*Function (F) variables: describe the teleology of the object, i.e. what it is for.*
- *Behavior (B) variables: describe the attributes that are derived or expected to be derived from the structure (S) variables of the object, i.e. what it does.*
- *Structure (S) variables: describe the components of the object and their relationships, i.e. what it is."*

Based on the FBS model and an extensive literature review in areas of engineering design and cognitive psychology processes, Howard et al.(2008) suggest a representation of design, including the cognitive process described as *analysis, generation, and evaluation*. The proposed model suggests that cognitive processes occur simultaneously as the designers work between function, behavior and structure of the design object. Therefore, in this sense it can be said that the precise definition of the design process is the lack thereof. As design consists of a number of cognitive processes, their sequence is not possible to define in time.

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[5] The definition of a process protocol is therefore the same as a design method.

Although the sequence of cognitive processes is not possible to map, design in practice is conducted in sequences of tasks. The sequence is however, not based on the process, but on the output, or deliverables, of the design process. In such a situation, coordination is possible based on deliverables as finalized pieces of information. The transfer of information between tasks is therefore concentrated in a single point of time, which, for instance, occurs in the form of design review meetings.

Many of such attempts, however, failed because of the intertwined temporal interdependence that design tasks exhibit between each other. Classical organization theory (see, for instance, Thompson 2003) defines tasks as reciprocally-interdependent when outputs of each task become inputs of other tasks in a way that each involved unit is penetrated by the other. Reciprocal interdependence is appropriate for *coordination by mutual adjustment* that calls for transmission of new information during the task execution process. Design, therefore, needs dynamic models that are based on distributed, instead of concentrated, information exchange throughout the design process.

The reciprocity of the links between product development tasks is found to be a consequence of the exchange of information between the upstream and downstream tasks in design. Krishnan's (1997) seminal work on overlapping interdependent product development tasks distinguishes options for overlapping based on the evolution of information in the upstream activity and sensitivity of downstream activity to changes in the upstream activity. Krishnan's (1997) concept distinguishes three types of information exchange and the corresponding concurrency modes of design tasks:

- Sequential mode where downstream activity only begins after receiving finalized information from the upstream activity.
- Parallel mode where upstream and downstream are developed independently from each other in a parallel process.
- Overlapped where the coupling between the upstream and downstream activities is preserved, but activities are overlapped and executed interdependently through frequent information exchange between the upstream and downstream.

A more recent elaboration of the idea of information flow between upstream and downstream yielded a theoretical and time-based coordination framework that uses data from the automotive industry to distinguish between the *stability and precision* of preliminary information exchanged in concurrent product development (Terwiesch et al. 2002). As one of the informants in their study illustrated the problem:

> *"Designing a car is much like building a house: you cannot afford to suspend the kitchen planning until you have put up the walls. But, if you start the kitchen planning too early, using preliminary floor plans from the architect, you are likely to do it twice."*

Based on different levels of information precision and stability, Terwiesch et al. (2002) suggest a combination of a *set-based* and *iterative* coordination of coupled problem-solving tasks based on preliminary information. In this framework, if upstream tasks release high precision preliminary information to downstream, the result is low stability information and a high likelihood of rework for downstream. By contrast, if upstream releases low precision and high stability information, the effect on the downstream will be either starvation (inability of nominal downstream to proceed due to too little information) or a deliberately chosen set-based duplication strategy that addresses multiple scenarios of possible outcomes.

Based on the findings from the above-mentioned studies in the engineering design field, cognition and the exchange of preliminary information between the design tasks can be defined as key issues of the design process. Finally, studying the design processes is the transition towards management practices.

## 2.7 SUMMARY

This chapter elaborated the difference between the hard and soft streams of design theory as objective and epistemic systems, respectively. The basis of rationality in the hard systems camp is analytical reductionism of the objective reality, while in the soft systems it is analysis of the socially constructed knowledge.

The body of design knowledge is summarized in this chapter along the two theoretical streams. The techno-physical conceptualizes design as *hard*, in that it is focused on defining the working steps of the design process, to minimize the subjective influence of the designer in the final product. It is prescriptive in nature and a number of design methods follow from this conceptualization.

The second approach is focused on the actual practice of design and as such it is descriptive. This concept is *soft* in that it defines design as *interactive inquiry,* where subjectivity and perception precede the objectivity of the hard approach. The concept of design as interactive inquiry does not include prescriptive design methods, the closest one being the *soft systems methodology*.

As a synthesis of the two research streams, researchers have studied the design process and concluded that, in contrast to the production process, the basis of the design process is cognition and information exchange which are very difficult to explicate in terms of process representations.

# CHAPTER 3:
# DESIGN AND ITS MANAGEMENT IN THE BUILT ENVIRONMENT

**Abstract:**

The present chapter transposes general design theory to the built environment design. Firstly, I summarize the most important theoretical basis of design in the built environment to define the domain-dependent narrative that characterizes the field. This domain-dependent narrative is based on differences between different disciplinary design languages, such as architecture and engineering. This chapter will establish the need for a domain-independent representation of design in the built environment and continue with a summary of the most-used design management methods in the built environment. In the chapter, I also summarize some of the promising methods for the advancement of design management. By encapsulating a wide body of knowledge in design and its management in the built environment, the goal of this chapter is to **set the stage for further theoretical development of domain-independent design management in the built environment**.

## 3.1 THE CONTEXT OF DESIGN

### *3.1.1 Introduction*

Following the theoretical interpretations from general design theory, the question arises of how do these concepts relate to the built environment?

The built environment is an artificial system that exists in the domain of not only physical, but also social reality. As a complex system comprising a diverse range of artifact-components, the built environment needs to exist in an abstract form before it can exist in the physical form. This abstract form of existence is in the realm of the designed system and this constitutes the object of analysis of this thesis.

A new built system is a product with many different levels of content, which result from a construction project as a unique effort to accomplish the physical system. From the inside shell of the product, the levels of content would be the system's overall spatial layout, architecture, engineering, and construction. The built environment system is, by definition, also embedded into its external context that consists of the environmental, economic, and societal systems. This complexity is what makes the design of built systems so complex.

The aim of this chapter is to introduce and apply design concepts to the built environment. Specifically, in the built environment design, the most prominent distinction is in the professional narratives of architecture and engineering. Due to these different narratives, the design process in the built environment is heavily based on the disciplinary fragmentation involvement, which is the main feature of the process.

### *3.1.2 Domain-dependent Narratives in the Built Environment*

The dominant development of design in the built environment has thus far led to an increasing fragmentation along the disciplinary boundaries of urban planning, architecture, and engineering systems. Put differently, urban planners have been understood to share an ontological understanding of design that is substantially different from both what architects and, even more so, engineers conceptualize in their design efforts. This has been common practice since the split of architecture and engineering professions and has been acknowledged in literature (Lawson 2005). As a result, urban planning and architectural design are defined as planning activities with a broad impact on not just physical world as we know it, but also on the society that comprises it. On the other hand, however, engineering has been reduced to a technical support role, outside the realm of creative design (Vermaas and Kroes 2007). This is also evident in terminology that clearly distinguishes the two concepts in the widely-used term of *design and engineering*. On the one hand, engineering implies a scientific mental model based on analysis, whereas design implies the constructive and creative mental model based on synthesis.

Vermaas and Kroes (2007) illustrate this situation as:

"*Engineers make things that work and architects order space, giving visual expression to the built environment.*" Moreover, "*architecture is perceived to be similar to the fine arts. Building owners may seek to enhance their own social position through association with the artistic authority of the architect.*" On the other hand, *"engineering is an objective science applied to specific problems"* is an interpretation which makes the disciplinary boundary of the design and engineering seem logical.

Scholars have coined various conceptualizations for design activities in the context of the built environment. This conceptual pluralism continues to fragment the field of design in the built environment by widening the knowledge gap between urban planning architecture, on the one side, and engineering systems, on the other. This led to a polarized conceptualization of design in the built environment. These two poles use complementary philosophical paradigms, they are supported by separate research streams, even at the practical level of organizational culture, they are very different, almost mutually exclusive mindsets[6].

### *3.1.2.1 Architectural and Engineering Design*

The design process is in the built environment is without any doubt led by architecture as a professional discipline. It is architects who are trained and expected to exhibit skills of soft design aspects. Consequently, literature in architecture is dedicated to the action-centric

[6] Although it is not specifically a comparison between architecture and engineering, a study by Ankrah and Langford (2005) gives a comparable example: they analyze differences between the design and construction organizational cultures.

and iterative process of designing artifacts, by taking into account aesthetic, social, psychological, and cultural criteria of value. A representative of this stream is Lawson (2005) who discusses architectural design thinking in the following way:

> *"We have seen that designers often develop early ideas about solutions long before they have really understood the problem."… "In some design domains the problem may be very clearly stated and success easily measured and thus the process may be more one of moving from problem to a solution which might be almost thought of as optimal. At the other end of the spectrum of design domains the problem may emerge more from an exploration of solution possibilities. Most design domains that we have explored in this book are between these two extremes and, as a result, problem and solution are better seen as two aspects of a description of the design situation rather than separate entities."*

This is clearly the kind of synthetic thinking that characterizes creative processes. Although in design there are also traditional problem-solving areas, it seems that architectural design school of thought concentrates on the synthetic kind of thinking that does not distinguish between design problems and solutions in terms of classical scientific thinking. These areas are left for the engineering disciplines whose role in the design process is delayed in comparison to architectural design. This temporal delay causes significant differences in the mental processes that this part of the design process requires. Firstly, by the time engineers are involved into the design process, the initial problematic situation (i.e. ill-structured problem) has already begun evolving into a structured problem to be solved with analytical-reductionist techniques. This is, perhaps, the reason why so many of the engineering design methods in the built environment leave out the conceptual solution planning and synthetic aspects of design.

The role of structural engineering, for example, is to avoid failure of the structure. The entire physical structure is for this purpose defined as a set of structural functions that need to be fulfilled in order for the structure not to fail. In this vein, Narayanan and Beeby (2001) describe the functional role of the wall as a load-bearing element of the structure in the following way:

*"Structurally walls carry out the same function as columns, that is, they transmit loads downwards. In tall buildings they also serve an important function in stiffening a building against lateral loads (i.e. wind). Architecturally they serve to divide up a building into compartments and to provide an outer skin. Generally walls are fairly lightly loaded. It should be noted that there are cases where walls function more like slabs than columns. An example of this is where a wall forms the vertical sides of a tank that contains liquid. Here the wall is mainly subjected to a horizontal load from the liquid and has to transfer this load vertically to supports. A wall that supports soil (a retaining wall) is similarly behaving structurally more as a slab than a wall."*

Consequently, the mode of thinking that the discipline of structural engineering employs is the application of scientific principles of classical mechanics that describe the behavior of materials and structural elements. It is clearly a problem-solving situation where the problem is posed by the conceptual solution and the solution is elaborated by using some of the well-developed calculation methods for structural analysis.

The above-described design process constitutes what is traditionally termed *engineering* in the design process in the built environment sectors. In the central European higher education system, the curriculum of the civil engineering profession devotes undivided attention to the structural engineering of buildings in the similar amount to what architecture schools dedicate to architectural design. Although this may seem self explanatory, my argument here is that the design process division in terms of *design and engineering* is inconsistent because it is based on the disciplinary divisions between architecture and civil engineering.

Indeed, architects have traditionally been designers of the built environment and the profession most certainly embodies vast amounts of knowledge on the design process. However, the view in which architects are assumed to be natural leaders of the design process can also be considered a shortcoming in its own right. Although this leading role may still be true in a large number of projects, the large number of disciplines participating in a substantial number of projects necessitates decentralized leadership of the design process (Gray and Hughes 2001). This implies that, while the concept of design in terms of architectural value will never be lost, it needs to be complemented with design paradigms from other participating disciplines. The same is, of course, true for the engineering design streams. Although the deductive approaches that the engineering design professional narrative uses are invaluable to making the structure fulfill its physical structures, it does not even approach the ill-structured nature of the design problem.

Within the existing domain-dependent design concepts, architectural designers are perceived more in terms of artistic creativity, while engineering designers are in their mental programs more aligned with hard-sciences approach. Although this conclusion is hardly debatable, it also clarifies that such claims are based on an implicit assumption that architects are artists and engineers are hard-core scientists. Although many would agree with this claim, the term of design and engineering is far from reality as both architecture and engineering engage in design activity.

This thesis will attempt to debunk this disciplinary belief in an argument for a domain-independent approach to design, while simultaneously acknowledging the specific features of design methodology that are a consequence of different disciplines. One of the most prominent pieces of planning literature summarizes this argument as follows (Rittel 1987):

> *"Everybody designs sometimes, nobody designs always. Design is not the monopoly of those who call themselves "designers". From a downtown development scheme to an electronic circuit; from a tax law to a marketing strategy, from a plan for one's career to a shopping list for next Sunday's dinner, all of these are products of the activity called design."*

This will also be a small contribution towards complex collaborative design processes such as concurrent engineering and participatory design that require significant management efforts to be successful.

### *3.1.2.2 From Architects and Engineers (back) to Building Designers*

As a consequence of industrialization, the professions of, architecture, engineering, and construction have been separating continuously. Since the abolishment of the *master builder* concept, a single person who was responsible for the entire building project the professions within the construction sector have been developing relatively independently of each other, with the main goal of achieving better quality, for instance through the separation of "designing and making". As it seems that the trend of the increasing specialization into narrow fields of knowledge is not going to stop, the need for effective management is also growing rapidly. As a consequence, the professions of construction and design managers have come into existence.

Although the architectural profession has always been the leader of the design process, they are now losing this position to project managers as an increasing number of engineering systems are being incorporated into buildings. In such a situation, the need to integrate architectural and engineering aspects of the design process becomes crucial. The following table depicts most prominent aspects of architectural and engineering design as it appears in the context of the built environment.

Based on the need for integration of the design disciplines emerged a number of methods that act at the interfaces of design components, for instance, in between architectural and engineering tasks. All this calls for a path where the design disciplines integrate around the artifact that they produce. This is not unlike the concept of *building design* that was also abolished with the differentiation of profession in the building and construction industry. The original concept of building design integrated the major design disciplines of architecture, and building engineering of structural, mechanical, and electrical engineering. This interdisciplinary concept, however, is very rarely found not only in the professional firms specializing in design, but also as part of the designers' education curriculum in universities worldwide.

| *Features:* | *Architectural Design* | *Building Engineering Design* |
|---|---|---|
| Design objective | Designing spaces and environments that will accommodate human activity. | Designing specific functions of the physical systems that will "make it work". |
| Success criteria | Criteria of architectural value: different schools of aesthetic, social and environmental value. | Functional criteria of structural, mechanical, and electrical systems. |

| | | |
|---|---|---|
| The basis of value | Symbolic, abstract. | Functional, concrete. |
| Mode of thinking | Iterative problem and solution synthesis, divergence. | Reductionist problem analysis, convergence. |
| Solution domain | Infinite | Sets of correct solutions |
| Narrative | Concepts, relativism, metaphors. | Numbers, hard facts, logic. |

Table 3: Characteristics of architecture and engineering based on the division of design professions

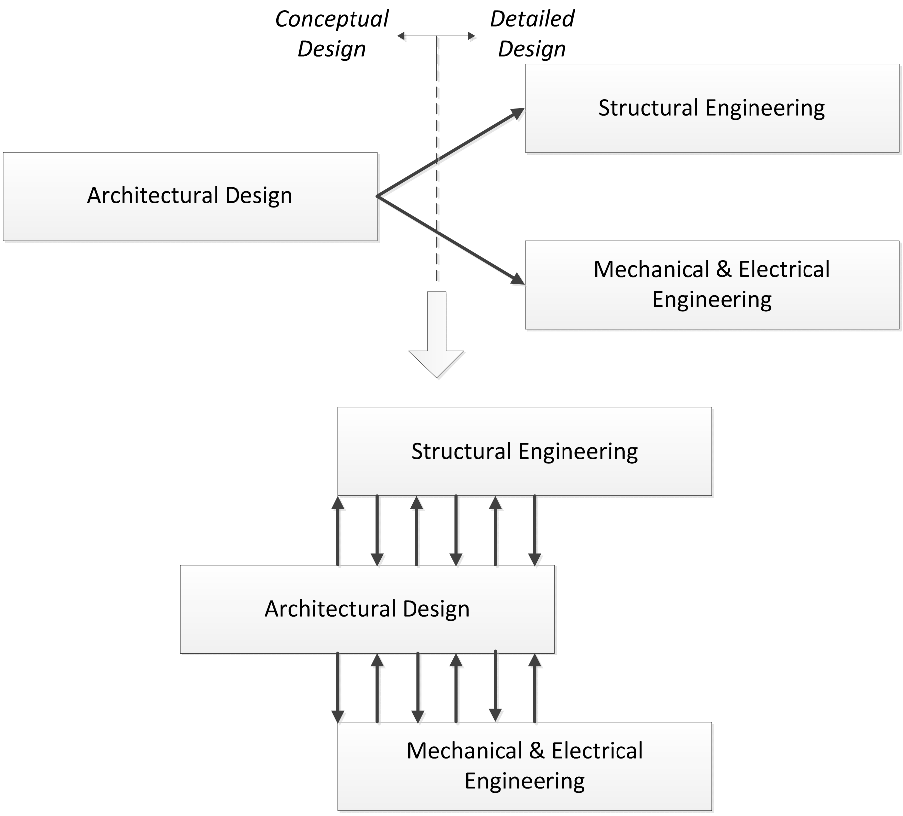


Figure 3: From architecture and engineering back to building design

Figure 3 illustrates the conceptual transition that is needed to accomplish a better integration of the designing professions within the built environment industries. More specifically, the illustration shows the transition from a disciplinary separation of design professions back into the old concept of building design. Various concepts have been coined to help this process, the most prominent ones being Building Information Modeling and Concurrent Engineering.

#### *3.1.2.3 Methodological Implications*

The domain dependent theoretical narrative in the built environment has significant implications for design methodology used. Although it belongs to a deep-seated disciplinary division, it is taken for granted that architectural design does not follow a well-defined procedure, and that it is evaluated in terms of architectural value, and fulfillment of the client's requirements. By contrast, engineering design is evaluated in terms of its functional value, which can be considered a much more mundane and interpretation-free criterion. This domain-dependent concept has even been institutionalized in the form of professional chambers and the corresponding normative frameworks.

In this sense, there is a lack of methodological support for architectural design, whereas structural design has been institutionalized to the level where it can be considered a practical methodology.

In Europe, this is the role of *Eurocodes*, which give detailed procedures for structural design of buildings. The set of 9 *Eurocodes* encompasses design of structures with different material characteristics. The Eurocode structural design method is based on more fundamental sciences such as material science and strength of materials. Other engineering fields in the built environment (i.e. geotechnical and hydraulic engineering) also use similar prescriptive design standards, but the relation between architectural and structural design is, in my opinion, the most obvious example of how design methods relate to different domains of knowledge.

#### *3.1.2.4 The Process of Design in the Built Environment*

Process-related research on design in the built environment is lagging behind other design sectors. The main reason for this is the current disciplinary fragmentation in the design process. Different disciplines work in a defined sequence that also determines the decision-making involvement of each discipline.

Some of the attempts to identify the overall process of design in the built environment include the Formoso et al. (2002) model for the process of house-building design, the *design structure matrix* method to determine the appropriate sequence of the tasks within the process (Austin et al. 2001), and the extensive *Process Protocol* that covers both design and construction processes (Kagioglou et al. 2000). A comprehensive overview of the process-related management concepts for design of construction projects is available in Tzortzopoulos et al. (2005). Given the erratic nature of the multidisciplinary design process, attempts to structure the design effort into distinct phases are of limited explanatory value.

A different approach advocates that design tasks need to be executed in parallel without a well defined sequence. As opposed to the traditional *arms length* approach where diferent disciplines in design barely influence each others tasks, in *concurrent engineering* design contributors communicate from the outset of the project and collaboratively work towards an integrated design solution. Anumba and Evbuomwan (1997), for example, from a contracting perspective argue for a concurrent approach in engineering of projects, where all the disciplines collaborate silmutaneously in an effort to reduce lead times of overall design. Since these findings were based on research in the manufacturing sector, further research was needed to implement the framework to study the concurrent design construction sector (Bogus et al. 2005, 2006). This research developed a methodology for assessing the characteristics of upstream and information and listed a number of overlapping strategies accordingly.

To overcome differences in the disciplinary narratives, designers interact through boundary objects, most notably, *drawings*. Whyte et al. (2007) studied patterns of interaction within design teams according to “liquid” and “frozen” states of a design version. They found different patterns of *freezing, unfreezing, and refreezing* design information. In their discussion, frozen design materials are unavailable for change, whereas fluid materials are open and dynamic.

As in other fields of design (see section 2.6), the social and cognitive features of design hinder its process-based explication.

## 3.2 THE CONTEXT OF DESIGN MANAGEMENT

### *3.2.1 Introduction*

As the previous section demonstrated, the design field is theoretically and professionally fragmented, and this is even more the case in the built environment. However, large structures are still delivered to the clients, structures that not only fulfill their functional requirements, but also act as symbolical artifacts of their respective urban environments. How are such buildings designed, when the overall practice of design in the built environment is so fragmented? The immediate answer to this question is that the design needs to be thoroughly *coordinated, managed, and led*. It is therefore the task of **design management** to deliver the integrated building that fulfills the needs of all the project stakeholders and the project coalition.

How can we then define design management in the context of the built environment? Throughout this thesis, I will use the following definition of design management:

**Design management is a process that subdivides and integrates the individual design contributions into a coherent set of information embedded into the overall project context.**

More specifically, the purpose of design management is integration by using a management rationale. Design management is, therefore, a **domain-independent** effort. The aim of this section is to disentangle the rationale of design management in the built environment and to summarize the corresponding theory as well as the most widely-used methods. Along with theory and the methods currently used, this chapter will also summarize a number of emerging design concepts that provide opportunities for further development of design management in the built environment.

### *3.2.2 The Basis of Design Management Rationality*

The practical basis of rationality in project management is the traditional triangle of time, cost, and quality (TCQ) that need to be mutually balanced for the effort to be considered successful. The underlying philosophical basis of rationality can be, however, much more difficult to determine. To my knowledge, the only such effort is given in Koskela (2000) who gave an extensive theoretical interpretation of production concepts used in the construction industry that also cover the area of design. Drawing from an extensive literature review Koskela (2000) developed three categories, in which all the available concepts in construction, including building design, can be placed:

- Transformation of requirements and other input information into product design. The transformation concept has dominated management literature since Henry Ford and Frederick Taylor in the beginning of 20th century laid the foundations of scientific management. The philosophical basis of transformation-based management reasoning is the application of neoclassical economic rationality to near decomposable systems. The central practical entity of this concept is *the task and work breakdown structure*.

- Flow of information, composed of transformation, inspection, moving and waiting. At the core of this concept is the *elimination of waste* or concern that what is not needed is done as little as possible. Lean production is another term for the flow concept.

- Process where value for the customer is created through fulfillment of the requirements. The focus of this concept is that the gap between the customer value and the product achieved value is as little as possible, therefore *to minimize value loss*.

Because the categories of transformation-flow-value (TFV) were developed for the production sector, they can also be considered a proof that design and production activities are fundamentally different from each other. In a paper referring specifically to design management of concurrent engineering processes in construction, Koskela et al. (2002) differentiate between design and production activity with F and V aspects that are much more prominent in design than construction.

Table 4 below gives an overview of different elements in the TFV concept and maps the concepts to the traditional basis of project management practical rationality. Transformation of inputs into outputs can be viewed as a formulation of the cost structure of the project, for example, through a structure of cost accounts whose execution is in later controlled. The flow concept adds the dimension of time to the T-based decomposition, and value adds the criterion of value.

| *TFV component* | *Description* | *Main practical concept* | *Relation to TCQ triangle* |
|---|---|---|---|
| Transformation | Hierarchical decomposition of scope through work breakdown structures | Task | Cost |
| Flow | Temporal decomposition of scope through tasks and the overall process | Process | Time |
| Value | Value-based decomposition of scope through elicitation of value and requirement management | Requirement | Quality |

**Table 4: Summary of the theoretical contributions in building design management**

In conclusion, although the TFV view provided a much-needed theoretical insight into the field of building design, it must also be said that, to a certain extent, it only justified the pragmatic basis of project management.

What is also visible from such a representation is that the three different concepts of rationality are neither independent, nor are they of equal rank. F and V concepts can, in fact, be interpreted as an extension of the T-concept. Because the scope definition is conducted through hierarchical decomposition, both value and flow aspects are attributed to elements of such a decomposed structure. The entire structure is firstly decomposed and then different properties (i.e. cost, duration, resources, and quality) are assigned to the elements of the structure.

This reasoning boils down to the classical concept of production project management where the main concern is (Morris 1997):

*"...first, what needs to be done; second, who is going to do what; third, when actions are to be performed; fourth, how much is required to be spent in total, how much has been spent so far, and how much has still to be spent."*

All this leads to the conclusion that the underlying current **basis of design management** in the built environment is **classical project management based on analytical reductionism**. This notion is the key to interpreting the available body of methods in design management that the following section introduces.

### *3.2.3 Theoretical Basis: Architectural Management and Design Integration*

#### *3.2.3.1 Architectural Management*

Architectural management is a theoretical stream of discussion and research that began developing rapidly in the last decade as a response to the management challenges within the architectural profession. In one of the relatively early works on architectural management, Emmitt (1999) sets the stage for this evolving field as follows:

*"Whatever the definition, the architectural management discipline is first and foremost concerned with people and communication. For example, the communication of an architectural firm's services (their people skills) to potential clients, the communication of information between people during the design and construction process and the control of these interactions, fall within the architectural management discipline. So, for this author at least, the term architectural management is used to cover all management functions associated with a competitive professional service firm. Project management, design management, construction management and facilities management are all covered by the umbrella of architectural management, areas of specialist interest which are themselves interdependent upon quality management and human resource management, lying at the heart of a firm's culture."*

It is visible that the author conceptualizes design as mainly a phase within a building project, whereas architecture is conceptualized as meta-knowledge about the building process and the built environment itself.

Within the architectural management research stream, communication is identified as the core substance in the (architectural) design process. Researchers focus on both more formal aspects of communication that is enabled by technology (den Otter and Prins 2002; Emmitt and Gorse 2006) and more informal collaborative aspects of multi-architect design collaboration (Sebastian 2003). In 2007, a special issue of Architectural Engineering and Design Management Journal, entitled: *Aspects of Building Design Management* further revealed the kaleidoscopic pluralism of research in this field. Published in 2009, the book entitled Architectural Management continued the dispersion of the discussion and contributed to the ill structure of how the field is defined and approached.

The stream of architectural management provides some very important contributions to knowledge in areas where traditional engineering and management-based approaches do not explain the reality sufficiently well. Sebastian (2004) calls this a social psychological approach that tries to acknowledge and approach the ill-structure of design problems.

As already mentioned in the beginning, this thesis will look critical upon this domain-dependent approach as, in terms of generality, this thesis defines design as meta-knowledge of every discipline rather than vice versa (a formal discipline being meta-knowledge of design). Being rooted in the field of architecture, the architectural management stream of literature tends to belong to the constructivist paradigm of design research.

#### *3.2.3.2 Design Integration within the Built Environment*

During the last two decades, the Architecture, Engineering, and Construction (AEC) sector has witnessed the emergence of a number of management concepts with the sole aim of reducing the fragmentation for which the sector has traditionally been considered notorious. More specifically, the fragmentation within the industry comes not only at the traditional boundaries of architecture, engineering, and construction; it is also a matter of internal fragmentation within each of the disciplines (see, for instance, Latham 1994; Egan 1998). *Integrated project delivery* is a common methodological umbrella to cover different approaches if reducing this fragmentation to make the industry more efficient (AIA 2007). One of the most popular approaches of integrating project delivery is to use the design/build method where the contractor assumes responsibility for the entire scope of work starting with client's project requirements (e.g., Anumba and Evbuomwan 1997). The focus of this type of integration is, however, limited to constructability of the design and does not encompass integration within each of the included disciplines extensively enough. Furthermore, design/build contractors tend to be organizations specializing in construction because the total costs of construction significantly exceed those of design activities (see, for example, Eldin 1991).

Within the design context, however, requirements need to be mutually negotiated between the stakeholders and the project coalition (Winch 2010). This significantly complicates the design decision-making process as interests of the client, the stakeholders, and the project coalition diverge. Additionally, the elicitation of requirements for the designed system is a tremendously challenging task because the requirements are often changing through time. As a consequence, what is considered integrated at the design/build interface, as a rule, can be oftentimes considered relatively disintegrated within the design context.

### *3.2.4 Design Management Methodology*

The available design management methods have either been developed from or incorporated into the *Systems Engineering* (SE) toolbox, a body of methods that started developing as early as in the 1940s. Since then, SE has been widely considered as the preferred methodology for managing the increasingly-complex engineering projects of 20th century.

The systems engineering toolbox gave birth to a number of methods that help design managers to coordinate the design process. Besides the classical project management techniques, which are casually used for design management, some more sophisticated methods are also used. These represent different adaptations of the *"Design for X"* idea that originated from engineering design methods body of literature (see, for instance, Pahl et al. 1996).

These methods are all representatives of the systems engineering camp, and they include value engineering, lifecycle cost analysis, constructability analyses, design structure matrix, and system dynamics.

*3.2.4.1 Systems Engineering*

The National Aeronautics and Space Administration (1995) defined the Systems Engineering methodology in the following terms:

> *"Systems engineering is a robust approach to the design, creation, and operation of systems. In simple terms, the approach consists of identification and quantification of system goals, creation of alternative system design concepts, performance of design trades, selection and implementation of the best design, verification that the design is properly built and integrated, and post-implementation assessment of how well the system meets (or met) the goals."*

From this definition it is clear that the structured approach advocated by systems engineering is best suited to manage well-structured problems with clearly-defined system boundaries. In the context of a well-structured problem, the process is, likewise, well-defined and consists in: defining functional, performance, and interface requirements, decomposing the project and allocating requirements to parts of the hierarchy, and integrating lower level parts of the hierarchy with their parent counterparts (NASA 1995). Each of these parts assumes a well-defined hierarchical structure that represents the relationships between parts of the system.

The systematic view of design supported by the interdisciplinary field of systems engineering yielded a number of useful tools to handle design as a structured problem-solving task. The purpose of this section is not to provide a comprehensive overview of the techniques used in the design process, but to give a brief overview of different areas of the application of the techniques. Most of the tools can be broadly grouped in the following categories of application:

- *Work breakdown structures, critical path method, organizational charts*. These represent the basics of any planning technique.
- *Requirement management*. This area of application concerns the analysis, tracing, and prioritizing the requirements for the technical system according to their influence on the system subcomponents.

- *Functional analysis* is a group of techniques for translating the abstract set of requirements into the functions of the technical system.
- *Design structure techniques*. Based on the need to exchange communication between parts of the technical system, this field of application forms a sequence of the design tasks to minimize the need for iteration in the design process.
- *Decision support systems*. Mathematical techniques, such as the *Analytic Hierarchy Process* and *Decision Tree*, are used to support the decision-making in the systematic design structure.
- Complexity reduction techniques such as *System Architecture* and *System Dynamics* that model the structure and behavior of the analyzed system.

*3.2.4.2 Value Engineering*

The concept of value is defined as the ratio between the delivered function and the cost of it. Unlike the concept of architectural value as an abstract quality such as, for instance, aesthetics, the concept of value engineering defines value in purely technical terms. Value engineering is a pragmatic discipline that consists of developing functional diagrams, which decompose the function of the overall system. In a discussion about the philosophy of value engineering and value management, Green (1994) explains the essence of the functional diagramming system:

> *"The logic of the diagram is based on the initial identification of the building's basic function, which is placed on the left-hand side of the diagram. This is then progressively broken down into subfunctions by the asking of a series of 'how?' questions. The accepted format dictates that each function (or subfunction) is defined by two words: a verb and a noun. The structure of the diagram is verified by it being ensured that moving from right to left provides the answer to 'why?'. It is interesting to note that function diagrams of this type are directly analogous to the value trees which have been developed by decision analysts for the purposes of problem structuring."*

In this way, value can be defined as the ratio between the desired function and the costs it will produce over the lifecycle of the product. As such, value engineering is a pragmatic discipline based on a number of supporting techniques, of which value analysis is the most prominent one. In this approach, however, value is defined as an attribute of the product that is fixed in time and does not depend on its interpretation. Therefore, the value engineering concept belongs to the toolbox of design as rational problem solving.

*3.2.4.3 Lifecycle Cost Analysis*

The method of lifecycle cost analysis is oftentimes used as a tool to help the value engineering decision making process. More specifically, to determine the value, costs need to be calculated over the lifespan of the project. In a research report, Kishk et al. (2003) define the field as:

> *"The systematic consideration of all costs and revenues associated with the acquisition, use and maintenance and disposal of an asset."*

In the same report authors also argue that the best time to use lifecycle cost analysis techniques is during the early stages of the project as this is where the highest impact is possible in terms of decisions being made. Although the value of using these analytical tools has been acknowledged in a variety of sectors, the construction sector is still lagging behind in terms of implementation of the concept. Another reason why this is the case in the construction sector is the following (Kishk et al. 2003):

> *"Cost data include initial costs, maintenance and repair costs, alteration and replacement costs, associated costs, demolition costs, and other costs. Cost data are essential for the research. However, without being supplemented by other types of data, they are of uncertain value. This is mainly because cost data need to be interpreted in the context of other data categories."*

Because the data is not collected and analyzed in a structured way for most buildings, there is an inherent lack of meaningful information on the lifecycle costs in the construction sector. Therefore, most of the calculations are still based on speculative values and as such are not reliable.

*3.2.4.4 Constructability Analysis*

The term of constructability was coined in the United States in 1986 by the Construction Industry Institute as ‘‘the optimum use of construction knowledge and experience in planning, design, procurement, and field operations to achieve overall project objectives.“ Since then, a broad area of knowledge has been developing in the field with the aim of achieving better integration of design and construction. In his keynote speech at the American Society of Civil Engineers assembly in 1992, Daniel Halpin illustrated the concept of constructability for the layperson in the following vein (Halpin 1993):

> *“When the composer Richard Strauss was in London for the rehearsal of one of his operas during the early part of this century, the principal oboe player approached Strauss at the close of the rehearsal to complain about the oboe part: "Herr Strauss, this part is too difficult to play on the oboe. I doubt if it is possible to play it with 10 fingers on the piano." Strauss looked at the part, scratched his head. "Yes, you are probably right," he said and turned and walked away. The great composer was saying "Well, I'm the designer/composer, it's not my problem. You are the player; you are just going to have to figure out how to play it."*

Indeed, as anecdotal as it is, this example clearly illustrates what the concept of sustainability is about. Oftentimes, however, designers lack the input that would enable them to produce a buildable design. Fischer and Tatum (1997), for example, categorized constructability input as knowledge on construction methods and products and suggested a sequence in which this knowledge should be communicated to the design team. In a practical setting, however, constructability issues are normally addressed within the constructability review meetings that both design and construction representatives attend and negotiate constructability issues. In a study focused on constructability review meetings, Arditi et al. (2002) found a generally high level of awareness about constructability among designers that is conducted in the following way:

> *“Peer reviews and feedback systems are the most prevalent tools used to achieve high levels of constructability. The popularity of peer reviews is attributed to the fact that some governmental agencies mandate this process for projects that meet established threshold limits. Most designers conduct constructability reviews in both the preliminary and developed design stages. Design professionals operating*

*in the general building sector perform constructability analysis in the conceptual and developed design stages significantly more than their peers operating in the engineering sector.“*

In conclusion, although the concept of constructability may seem tautological to a layperson, its importance cannot be overestimated. An increasing number of construction projects undergo regular constructability review meetings to ensure that the interface between design and construction is as seamless as possible.

One of the methods that support constructability of the building is the three-dimensional and four-dimensional (3D/4D) modeling concept introduced as an idea in the 1980s, but adopted into the practice of construction later. Researchers have repeatedly shown that using the 3D/4D modeling concept significantly improves constructability of design on complex projects (see, for example, Hartmann and Fischer 2007).

#### *3.2.4.5 Design Structure Matrix*

The design structure matrix is a method to structure the relationships between different design elements. These relationships help us understand the behavior of the system, although not in the form of linear superposition. Matrix structure captures both the sequence and the technical relationship of the design tasks. It does so by decomposing a complex system into respective subsystems, by noting the relationships between the subsystems and by noting the input and outputs of the systems. A DSM is a square matrix with identical row and column labels. Reading across a row reveals what other elements the element in that row provides to; scanning down a column reveals what other elements the element in that column depends on. That is, reading down a column reveals input sources, while reading across a row indicates output sinks. Browning (2001) classify the application of DSM into the following categories:

- ***Component-Based or Architecture DSM:*** Used for modeling system architectures based on components and/or subsystems and their relationships.

- ***Team-Based or Organization DSM:*** Used for modeling organization structures based on people and/or groups and their interactions.

- ***Activity-Based or Schedule DSM:*** Used for modeling processes and activity networks based on activities and their information flow and other dependencies.

- ***Parameter-Based (or Low-Level Schedule) DSM:*** Used for modeling low-level relationships between design decisions.

For each of the methods, we look at the interactions between the system elements. Those interactions can take forms of *space, energy, information, and material.* In the example of Organization DSM, different design teams are linked by how much they interact. This can be found out either through interviews, or by observation. Subsystems are then grouped in clusters which show the higher level of organizational interdependency in terms of input and output of information. Since the design process is information intensive, the technique of DSM leads to *lean* systems engineering process. This can be achieved by eliminating unnecessary communication between unrelated parts of organization, and emphasizing it between the more related parts. DSM technique also helps system engineers to explicitly express the subsystems by analyzing their interactions. Summarizing, DSM matrixes show not only what systems consist of at micro-level, but also help in structuring parts to clusters, in defining their relationships, and minimizing the content of project information (Austin et al. 2000; Austin et al. 2001; Yassine and Braha 2003).

### *3.2.5 The Need for Interpretive Design Management in the Built Environment*

After the above elaborations, it becomes clear that the available methodology of design management belongs to the hard systems camp. Systems engineering offers a comprehensive methodology that takes into account the numerous components of the analyzed system in a holistic framework of methods. However, all of these methods assume that the best solution is required for a well-defined problem. As such, these methods are not useful when the exact problem still needs to be discovered, a most likely encountered situation in realistic situations, where defining the system is the main challenge.

Although reductionist methods are currently the only way to make complex management problems formally solvable, they represent the world essentially as one well-assembled machine. In the design of technical systems whose main purpose is to deliver a set of technical functions to their users the systems engineering toolbox is an invaluable methodology to realize such systems. However, when the human factor is more represented within a system, the hard approach also has shortcomings. The main shortcoming of all the hard approaches is that they concentrate on the designed artifact and design boundary objects, while they disregard the non-linear behavior of design agents as human protagonists of the design process. The following table (Table 5) summarizes the available body of design management methods.

| *Design Management Method* | *Management Problem* | *Interface* | *Purpose* |
|---|---|---|---|
| Work Breakdown Structure | Define scope through subdivision | Physical interfaces defined | Linear decomposition |
| Gantt Chart | Define sequence of execution | Temporal interfaces defined | |
| Resource Allocation | Define organization | Organizational interfaces defined | |
| Value Engineering | Optimize value | Designer – Client integration | Integration (design for X) |
| Lifecycle costs analysis | Minimize lifecycle costs | Designer – Client integration | |
| Constructability | Achieve constructible design | Designer – Contractor integration | |
| Design Structure Matrix | Minimize need for iteration | Designer - Designer integration | |

**Table 5: Summary of decomposing and integrating design management methods**

What is immediately obvious from the summary table is that none of them explicitly acknowledges the learning aspects in design as well as the process of social interaction, through which design is created. They are all prescriptive and can be applied when the system has been defined previously.

To study the knowledge acquisition concept of design is, therefore, similar to the process of *theoretical inquiry*. Therefore, a variation of the scientific method could be implemented to develop the soft design approaches. The scientific method can be defined as the acquisition of new knowledge through an iterative loop of assumption, analysis, and integration with previously acquired knowledge. This is also in line with the *learning system concept*, often mentioned in the soft systems literature. By contrast, the hard methods are all based on the logic of *hierarchical decomposition* with the application of rationality as defined by classical economics. It is a combination of the two that would complete the field of design management methods. Such a combined approach to the study of decision-making would facilitate the transition towards theoretical explanations of complex concepts such as participatory design and sustainable design as the next section will demonstrate.

### *3.2.6 <u>Opportunities for Advancement</u>*

The main difference between the systems engineering camp of methods and the soft systems thinking is the conceptualization of the problem. Whereas in the systems engineering camp, the problem is considered as given, in the soft systems camp, design includes learning about and defining the problem which is subject to interpretation. Recently, a number of design concepts have emerged, which explicitly acknowledge the interpretive nature of the systems. Therefore, such concepts provide an opportunity of the advancement of design management methods and further transition towards the learning paradigm. For this reason, this section will briefly introduce the design concepts enumerated below:

- Value Management
- Sustainability
- Scenario-based Planning
- Participatory Design
- Agile Product Development and SCRUM
- Building Information Modeling

These concepts represent a significant step in the transition from hard to soft design management methods in the built environment. This transition is evident in the increasing number of design management approaches that incorporate interpretive aspects of design. Instead of focusing on engineering of well-structured systems, these methods are focused on a structured process of learning about the system.

*3.2.6.1 Value Management*

To the author's knowledge, the only approach in design management that acknowledges the learning aspects of design is *value management* that seeks to define value prior to its engineering and delivery. In this approach, value is equated with perception instead of being considered an inherent characteristic of the analyzed object. Thomson et al. (2003) summarized the concept of value as:

> "…*the relationship between positive and negative consequences (output and input, or benefits and sacrifices). More specifically:*
>
> - *Value does not exist it is own right, but is an assessment of an object*
> - *This assessment occurs in a context and is framed by characteristics of that context*
> - *Value assessment can be subjective when framed against an individual's values, or objective when the relationship between benefit and expense is compared*
> - *Expense can be either resource consumption (time, money, people) or emotional effort (stress, attaining and maintaining buy-in)*
> - *Value may be influenced by the time at which it is judged or assessed."*

This involves learning about the design problem in accordance with the Soft systems learning paradigm introduced in the previous chapter. Green (1994) defines value management as:

> *"…a structured process of dialogue and debate among a team of designers and decision makers during an intense short-term conference. The primary objective of value management is to develop a common understanding of the design problem, identify explicitly the design objectives, and synthesize a group consensus about the*

*comparative merits of alternative courses of action. Value management makes no pretence about finding optimal answers; it is solely concerned with establishing a common decision framework around which participants can think and communicate."*

As another one of the prominent methods of value management, I present the *quality function deployment* concept as a useful technique to structure the engineering effort according to the client's requirements. This concept uses the so called *house of quality*, a table that on its one side maps the client's requirements and on the other – the organization's response to those requirements. Ahmed et al. (2003) have shown that the method can be used in the briefing stage of construction capital investment advantageously.

Male et al. (2007) implemented the soft systems learning paradigm into the concept of value in construction projects and developed a framework for value management in the construction industry. This framework consists of four different learning styles:

1. "*Where a value manager works with an existing team to assist them to understand value problems, structure thinking and develop a way forward.*
2. *Where a value manager works with an existing team and the objective is to challenge and introduce change*
3. *Where a value manager brings together an independent tailored team of specialists for an audit study*
4. *Where a value manager brings together a tailored independent value team of specialist for a value audit and reconfiguration."*

Except for the last example, the other value methods do not explicitly acknowledge the learning concept. However, they still employ the interpretive definition of systems, which is a way forward towards the soft approach.

#### *3.2.6.2 Sustainability*

The concept of sustainability made the political agenda in the 1970s as a result of the global energy crises. The main idea of sustainable development is one that the mankind needs the kind of development that can sustain itself indefinitely. Since the construction sector makes up roughly 10% of worldwide GDP, it is a logical development that the concept of sustainability migrated into the construction sector relatively quickly. Sustainability is normally conceived as a system comprising three components: environmental, social, and economic. Quite obviously, the exact definition of sustainability as applied to the construction and built environment sectors is still problematic, but nonetheless, the concept is currently so often heard that is can be considered a buzzword of our time. Currently, the application of sustainable building has seen its application through a number of formal certification systems that are applied mainly at the national level. Such systems elaborate a list of topics and criteria that determine the level of sustainability for a building. These topics are mainly taken into account through a summarizing aggregating set of values that determines the overall sustainability of the building.

Needless to say, sustainability is surely a topic with a broad potential to apply the learning systems paradigm. The existing methods, however, treat the area as if it is well-defined and in this way, for commercial reasons, they obscure the need to conduct an immense amount of research in the area of sustainability. This research is first of all needed to define the different aspects of sustainability that cannot possible be covered by such simplistic terms as lists of sustainability criteria included in the practical methodologies.

As an immense amount of literature has been dedicated to some aspect of sustainability in the construction sector, this section will not further go on with elaborations of the sustainability within the built environment. A comprehensive overview of the concept of sustainable building and the corresponding building performance evaluations for the Central European institutional environment is available in Kovacic (2008).

#### *3.2.6.3 Scenario-Based Planning*

Another approach used in long-term planning of complex projects is scenario-based design that identifies a set of possible scenarios for how events might unfold given the different circumstances. Based on the identified set of scenarios, each is then elaborated using the available design methods. The concept comes from military strategy, but has been applied in the automotive sector, as firstly put forth by Toyota. A study by Sobek et al. (1999) defines the set-based design strategy in Toyota as:

> *"Design participants reason about, develop, and communicate sets of solutions in parallel and relatively independently. As the design progresses, they gradually narrow down their respective sets of solutions based on additional information from development, testing, the customer, and other participants' sets. As the design converges, the participants commit to staying within the set(s), barring extreme circumstances, so that others can rely on their communication."*

Although I am not aware of any publications on scenario-based planning used for the built environment design, this concept provides an invaluable opportunity to integrate the available design methods into a coherent approach. This can be applied into design of such projects that belong to highly-regulated sectors such as, for instance, health-care. In such cases several distinct policy developments are possible to determine and each of those needs to be followed by a corresponding design approach.

#### *3.2.6.4 Participatory Design*

Participatory is a design concept that aims to involve all the stakeholders in the design process to achieve the desired functions of the design, most notably, from its users' perspective. This approach is used in urban design and architecture, for public projects with a high stakeholder involvement. It is a complex social process that involves a dialogue between participants that use very different narratives and conceptions of the design. In a study involving architects' interaction with the users, Luck (2003) concludes:

> *"The social process of dialogue facilitated the exchange of information and enhanced the designer's understanding of the needs and expectations of future building users. Several themes emerged from this review;*

- *That generalization, extrapolating user preference to a broader population, should be approached with caution.*
- *Tacit knowledge, giving insight into user experience of an environment, can be revealed through discussion.*
- *Descriptive narratives and metaphors can reveal tacit knowledge.*

- *Users suggesting 'solutions' can limit a design solution.*
- *In some situations, such as discussing the appearance of the building, language use was limited and the absence of a common vocabulary or architectural language limited the discussion to very basic constructs"*

In such a complex social process of a multiple-instances dialogue, the importance of methods based on the learning paradigm cannot be overestimated, especially in early design stages.

*3.2.6.5 Building Information Modeling*

Because design is an interactive, not intramental[7], activity between the human designer and the designed artifact, modeling is the central issue of virtually every design concept. Such models cover the range from producing rough sketches with paper and pencil to detailed mathematical and geometric models of the designed artifacts. In the built environment design, the prevalent modeling methodology is *Building Information Modeling (BIM)*.

From physical models that architects use to present their ideas in the architectural competition, to the immensely-complex three-dimensional *computer-aided-design* (CAD) models of buildings and infrastructure, modeling is pervasive in designing construction projects. Simply put, a model is a simplified imitation of the reality. The model is valuable when it imitates reliably only those aspects of the reality that are relevant for decision making (Simon 1996/1969). Ever since the advent of the information technology, the built environment has seen a proliferation of software for every imaginable aspect of design. The present state-of-the-profession is such that CAD models are used as a basis for visually modeling the physical geometry of the building. The CAD models are subsequently used for conducting automated calculations in different areas of engineering design. A traditional way of representing information in the buildings has been through drawings: two-dimensional sketches and detailed footprints and elevations. Indeed, every architect or engineer in the built environment will consider those as a modeling basis, regardless of the available modeling technology.

[7] For a convincing elaboration of the intramental (i.e. intellectual) and interactive notions of cognitive activity and design, see Gedenryd (1998).

Through time, however, it has been repeatedly shown that much more information would be advantageous to model than what is the traditional practice of 2D drawings, text, and calculations. In a broad literature review and a practitioner-oriented discussion, Succar (2009) defined BIM as an integrated concept consisting processes, policies, and technology.

Although, indeed, the field of BIM does imply a number of interrelated organizational, process, and even institutional issues, this kind of a representation might be overemphasizing the importance of BIM. More specifically, this thesis views BIM as a modeling concept, that is, a tool instrumental to decision-making. In this light, the amount of information and the knowledge-domain areas that are explicitly or implicitly related to BIM, are not as important as the usefulness of the model as a decision-support-system.

Indeed, Hartmann et al. (2008) concluded that the 3D/4D functionality has been on a number of major construction projects normally used to only support a very limited number of decision-making aspects, whereas the model could have been used to support a much wider area of decisions. In this light, more than the modeling itself, what becomes more important is *what to model* and *when to model*. In conclusion, the quality of BIM and simulation models should only be viewed in the light of their decision-making value. A good model, therefore, models only those aspects that contribute to the decision-making and does not model other aspects (Simon 1996/1969).

#### *3.2.6.6 Agile Product Development and SCRUM*

Although the original principles of *Agile* were developed for the software development field, they can also be viewed as a basis for managing any process of a similar level of uncertainty. Unlike the traditional management approaches, such as for instance Six Sigma, that discourage changes in the process, the agile project management embraces the fact that product development is fraught with changes that might considerably affect the project outcomes.

SCRUM is one of such product development methods, which acknowledges that the maximum of flexibility in the process will yield the most successful outcomes in uncertain environments (Schwaber 2004). Schwaber defined the characteristics of the SCRUM projects as follows:

- *“Flexible deliverable: the content of the deliverable is dictated by the environment.*
- *Flexible schedule: the deliverable may be required sooner or later than initially planned.*
- *Small teams: each team has no more than 6 members. There may be multiple teams within a project.*
- *Frequent reviews: team progress is reviewed as frequently as environmental complexity and risk dictates (usually 1 to 4 week cycles). A functional executable must be prepared by each team for each review.*
- *Collaboration: intra and inter-collaboration is expected during the project.*
- *Object Oriented: each team will address a set of related objects, with clear interfaces and behavior.”*

Although theoretical elaborations of agile project management methods such as Scrum are very scarce, they have been widely advocated for product development in small and dynamic project environments. It is still needed to theoretically explicate why agile theories work better for the dynamic environments than traditional project management based on the positivist philosophy and the hierarchical structures. The following section will attempt to extract several theoretical aspects that might be helpful in synthesizing the two design paradigms and the development of an integrated body of knowledge and methods that includes both the systematic and agile concepts.

The potential of applying the agile project management methods in the construction sector has been identified relatively recently. Owen et al. (2006), for example conclude that agile project development methods offer significant:

> *“...potential for application in pre-design and design but that there are significant hurdles to its adoption in the actual construction phase.”*

Koskela and Howell (2002) continue noticing the potential of SCRUM in the construction sector and differentiate the method from traditional project management as follows:

> *"Scrum deviates starkly from the conventional project management doctrine. Two outstanding differences are that there is no Work Breakdown Structure, and that dispatching decisions have been totally decentralized."*

In a relatively recent study, Reymen et al. (2008) develop a SCRUM-based method for real estate development and find that the method is applicable in the built environment projects. In conclusion, the design in the built environment needs a theoretical explication more aligned with the agile software development methods than the traditional production project management.

*3.2.6.7 System Dynamics*

System dynamics is a method that accompanies the theoretical concept of systems thinking. The method itself is generally attributed to have been put forth by Jay Forrester and his research group at MIT in the 1960s. Although it is a "hard" method, it implements the cause-and-effect loops advocated by the "soft systems" stream. According to Forrester (1994), the method incorporates the following working steps:

1. Describe the system
2. Convert description to level and rate equations
3. Simulate the model
4. Design alternative policies and structures
5. Educate and debate
6. Implement changes in policies and structure

Each of the working steps determines not only the following steps, but also the interdependency is between the subsequent and previous steps, thereby defining an iterative process. The applicability of the systems thinking method has a wide range, as it has been shown to simulate experts' reasoning quite reliably. Winch (1993), for instance, described how a system dynamics model improved the consensus building in a complex decision-making environment of a construction project. In conclusion, the system dynamics modeling approach can be considered as a way to translate the soft systems thinking constructs into hard and quantifiable systems for analysis. This can be done on the basis of number of system dynamics models based on the learning systems paradigm.

### 3.3 SUMMARY

This chapter laid out the theoretical foundations of both design theory in the built environment and design management methodology in the built environment. By summarizing the theoretical foundations of design theory, the first section of the chapter argued that the built environment encompasses both the hard and the soft stream of design thinking and this is the most evident in the professional distinction between architectural and engineering design. In such a setting, the definition of architectural design is very much aligned with design as interactive inquiry, whereas engineering design is more aligned with the techno-physical approach. This is even reflected in the design methods, as they are mostly available for engineering design, whereas architectural design is only defined with relatively loose prescriptive frameworks. As a consequence, process representations of design are of limited value as they do not convey the interactive and cognitive aspects of the design process. The chapter then continued with establishing **the need for a domain-independent concept of design** in the built environment, where both streams of thinking would be represented. This is a trans-disciplinary concept that would require a change in the current professional mindset, which is disintegrated along the boundaries of architecture and engineering. However, to achieve this integrated concept, significant management efforts are needed, which is elaborated in the following section of this chapter.

This section summarized the most widely-used design management methods in the built environment and established the need to **advance design management with a more structured acknowledgment of the learning aspects** of design. The section demonstrated that the design management methods currently used can be classified as traditional production project management, even though the difference between design and construction has been widely documented in literature. **The advancement of design management from a positivistic into the interpretive area is, therefore, needed and vast opportunities to do so exist**. Representatives of these complex design concepts include sustainability, scenario-based planning, participatory design, and building information modeling. They can be viewed as a practical framework to support the development of interpretive design management in the built environment. This should lead to a domain-independent concept of design management that the next chapter will attempt to draft.

# CHAPTER 4:
# PROCESS-LEVEL DESIGN MANAGEMENT


**Abstract:**

Previous chapters of the thesis elaborated the available theory and methodology of design management, and implemented them to the field of the built environment. The aim of this chapter is to develop a **management framework for process-level design management** that takes into account the specificities of design as both a problem-solving and interactive inquiry human activity. The focus of the analysis in this chapter will be the process-level of design management or, more specifically, **system decomposition and task isolation**. I will subsequently validate the theoretically-derived management framework by using data from a **case study conducted on a large infrastructure project** that faced issues with design integration. Based on the validated theoretical framework, I will extract **a number of theoretical contributions and practical recommendations** that might be useful in the further development of design management methodology as well as for practical design management on projects.

## 4.1 THEORETICAL FRAMEWORK

### *4.1.1 Introduction*

As described above, the systematic problem-solving school of design assumes that problems are identified up-front and static in time. In this setting, design is a problem-solving task that acknowledges the ill structure of the problem formulation through iteration cycles. By contrast, the phenomenological representation of design gives an interpretive description of design. It is subject to great variations based on personal impressions on reality, individual human character, and psychological context of the problematic situation. Besides the development of technology to support the designing process, at the fundamental level, not much integration has been accomplished in design as domain-independent discipline. The problem-solving insights belong to the camp of systems engineering prescriptive design methods that firmly state how thighs *should be done* in order to achieve the design of the desired quality. The action-centric insights, by contrast, are more aligned with making sense of what designers *actually do,* and as such are of largely descriptive nature. The shortcomings of the two streams of thinking are therefore:

- The problem-solving stream presupposes a symmetrical relationship between the design and production processes, which is not realistic.

- The action-centric stream says nothing about the process, offering no opportunity for improvement in the ways of working.

The aim of this chapter is to extrapolate from the current state of development in design knowledge and suggest a framework that unifies the problem solving and the action-centric approaches at the process-level of design interdependence.

### *4.1.2 Decomposing the Wicked Problem*

The fundamental theoretical conflict between the two philosophies has, to date, not been resolved. The interactive inquiry theory neglects the ability to structure the process, the basic assumption of hard design methods. By the same token, proponents of the interactive approaches hardly acknowledge the social-psychological complexity of the interactive inquiry. What ca, however be said about the developments of the two streams is that **problem-solving theories converge to the prescriptive, while interactive theories converge to the descriptive modes of representation**.

The fundamental difference between the two conceptualizations is the concept of **process-level interdependence** that hinders the articulation of the wicked problem, thereby depriving reflection-in-action process representations of their predictive value. Although a process map can be assembled for any human endeavor or even experience, the question is how to represent only the important aspects, and disregard the others.

The following figure (Fig 4) attempts to disentangle the issues in design by dividing the wicked problem into the components of techno-physical and social-psychological complexity. The logic of the theoretical framework uses the principle of **linear superposition** at the meta-level of theory building to **decompose the wicked problem** into its aspects of techno-physical and socio-psychological complexity.

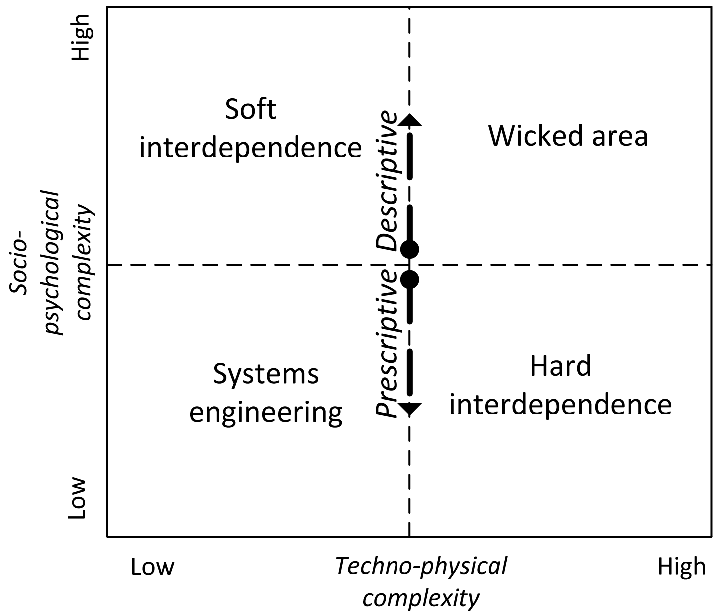


Figure 4: The linear composition of the wicked problem

The framework posits that the wicked problem should be solved by employing both theoretical streams to tackle hard and soft aspects of process interdependence. Techno-physical complexity produces **hard interdependence** that, although it might be difficult to discover, it **does not exceed** designer's **cognitive limits of information processing**.

Socio-psychological complexity, on the other hand, produces **soft interdependence** whose main feature is that is **exceeds** the designer's **abilities of comprehension** as it causes the system to behave in a chaotic way.

The remainder of this chapter will elaborate the two above-introduced domain-independent categories of process-level interdependence in design with the aim to explain the design process in a more realistic manner than the currently-used theories.

### *4.1.3 Hard and Soft Interdependence*

The previous chapters made the argument that the basis of design management should be domain-independent and, at the same time, it should acknowledge the interdependence between the design elements, unlike the hierarchical subdivision from classical project management. This section will elaborate the phenomenon of design interdependence from two perspectives: *scope and temporal sequence.* The former is a representative of the hard and the latter of the soft stream of design thinking.

#### *4.1.3.1 Hard Interdependence: Problem and Solution Domain Interdependence*

*"...it can be easy for the designer to become trapped in an iterative loop of decision-making, where improvements in one part of the design lead to adjustments in another part which lead to problems in yet another part. These problems may mean that the earlier 'improvement' is not feasible. This iteration is a common feature of designing."* - Cross and Knovel (2000)

One of the most important features that distinguish the cognitive activity of design from physical activities is the notion that **problem formulation and problem-solving are not two separate tasks, but rather one indivisible phenomenon**. Although this is not the kind of problem encountered in soft systems, it is an inherent feature of complexity in design management.

A theoretical concept that unifies these two representations has been firstly put forth by Maher and Poon (1996) and subsequently elaborated in a study involving industrial designers by Dorst and Cross (2001). Both studies contend that problem and solution spaces evolve concurrently during the design effort. The concept of co-evolution suggests that both the problem and solution oscillate until the design process achieves equilibrium. Because of this, design problem-solving cannot be represented as a mathematical function that transforms inputs from a fixed domain space into outputs. Instead, design problem-solving is a divergent iterative function without a fixed domain space. The concept of co-evolution was originally developed by Maher and Poon (1996) and for the purposes of this discussion it has been adapted and refined as shown in the next figure (Fig 5)

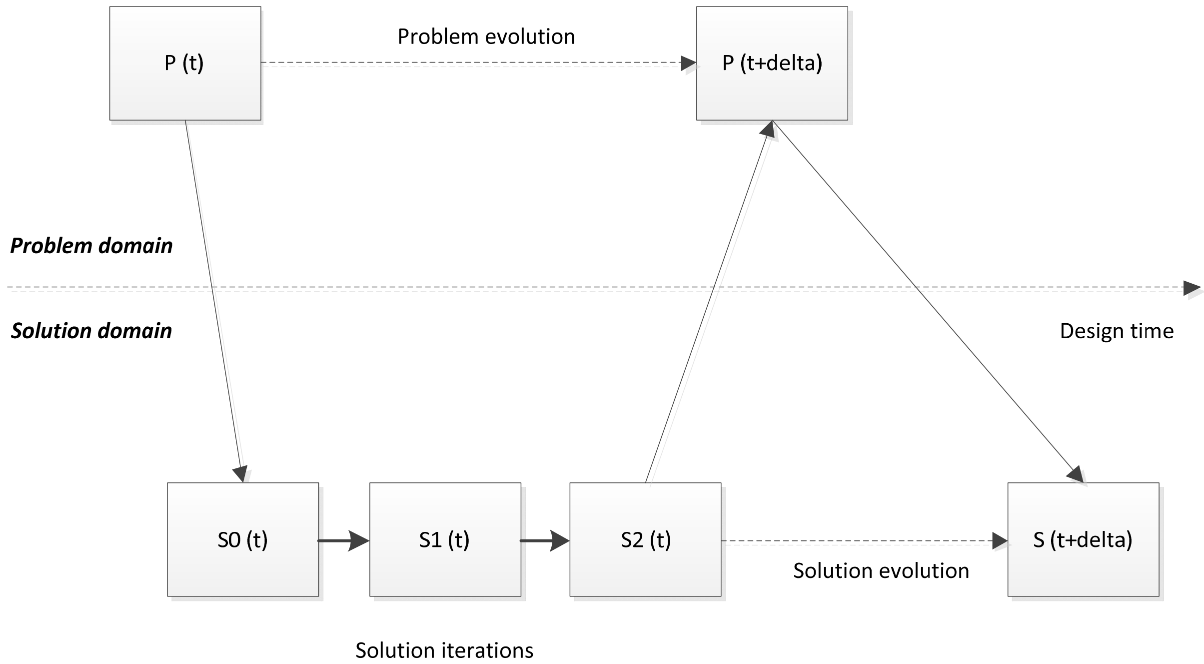


Figure 5: The concept of problem and solution co-evolution

This representation shows the erratic process of problem formulation and solving in design. The domain jumps are not only a consequence of frequent leaps in the creative process, but also a feature of the design on the technical level. In other words, the problem formulation and solution process changes domain space as design proceeds.

#### *4.1.3.2 Soft Interdependence: Convergence of Information*

When the temporal dimension is taken into consideration (see subsections 2.6 and 3.1.2), the basis of the design process is **the timing of decisions and information exchange**. In other words, the problem of which decisions will be taken when and with what input. When this is coupled with uncertainty caused by the preliminary nature of the information being exchanged in key points, it becomes clear that temporal interdependence in design belongs to the **soft area**.

In this sense, the design process is viewed as a stream of information exchange and processing. To explain this, let us consider an ongoing bundle of design tasks. This bundle of processes would normally produce several information flows. The first such stream is input is information in the form of either the client's set of requirements or requirements resulting from the local building codes and standards. In this case, the design process is bound to information created in the past and transferred to the design teams. This information can in most cases be considered static as the design team, as a rule, has no influence on it. This is the **adaptive mode** of design because current design needs to comply with, or adapt, the requirements created in the past.

The second information flow is the information produced by ongoing design. This information will have a constraining role on the design in the future timeframe; therefore, this section will call this the **constraining mode** of design. In this case, the production of current design creates requirements that future design will need to adapt to. The following figure (Fig 6) depicts the adaptive-constraining (A-C) concept of the design process.

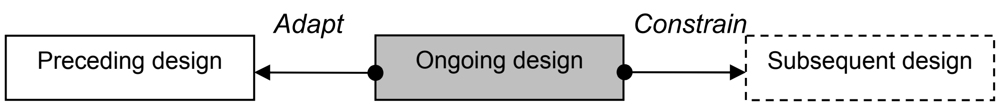


Figure 6: Adaptive-constraining (A-C) concept of design

The adaptive and constraining characteristics are inevitable in any design activity and this section will use this concept to theorize sequential and concurrent strategies of design execution, described in subsections 2.6 and 3.1.2 of this thesis. As identified in these sections, the main difference between sequential and concurrent strategies in design is that in sequential design, finalized information is transferred from the upstream towards the downstream. When two nominally-sequential tasks are executed in parallel, however, the nominal downstream has to begin while the problem solving in the nominal upstream still has not converged into its finalized stage. Thus, the effective concurrent process relies upon the exchange of preliminary, rather than finalized, information (Terwiesch et al. 2002). The corresponding nature of information exchanged is either liquid, and therefore subject to change, or frozen, therefore unavailable for change (Ewenstein and Whyte

2007). The table below (Table 6) summarizes the relationship between sequential and concurrent organization of design.

| ***A-C Features of the process*** | *Sequential Strategy* | *Concurrent Strategy* |
| --- | --- | --- |
| **Principle** | Ongoing design receives finalized information from upstream and processes it. | Ongoing design receives preliminary information from the upstream and processes it. |
| **Information exchange** | Delayed large batches of information: Earlier designs considered requirements for later designs. | Frequent small batches of information: requirements discussed and addressed jointly. |
| **Advantages** | Reduces design complexity and costs | Reduces latency, increases integration |
| **Shortcomings** | Produces sub-optimal solutions, design errors, and problems with integration | Explodes the number of requirements to address, costly |
| **Suggested use** | Independent design decisions | Joint design decisions |

Table 6: Relationship framework for sequential and concurrent strategy

Every design process should use both modes of information exchange, when appropriate. In the sequential strategy, ongoing design receives frozen information from upstream; therefore, information is **approximated as stable** and certain. In concurrent strategy, however, information received from upstream is **liquid** and, therefore, subject to change and uncertain.

The difference in the two approaches is how they address changes. In concurrent design this corresponds to participatory problem solving by multiple stakeholders that is commonly conducted in the form of interdisciplinary design review meetings. In sequential design, changes are, however, more difficult to implement as they imply rework in the previous phases.

The greatest shortcoming of the sequential strategy is in the suboptimal design solutions that are produced as a consequence of a lack of communication between the individual design contributions. This means that the individual part of the overall design will not be integrated appropriately. On the other hand, the greatest shortcoming of the concurrent strategy is in increase in complexity.

**The role of process-level design management** is therefore to **switch the information exchange strategy** in the design process between sequential and concurrent as appropriate, on the basis of an assessment of the adaptive constraining features of the design decision currently made. In the sequential strategy, integration is the main management concern, whereas in the concurrent strategy, it is reduction of complexity.

The next section provides validation for the derived theoretical framework by using empirical data from the case project.

#### *4.1.4 Process-level Envelope of Design*

Putting together the two paradigms of design thinking a unified framework can be assembled. This framework is a diamond-shaped diagram consisting of two poles (Figure 7). In this conceptualization, the design begins with a vague perception of the problematic situation. From this point, the design progresses as a divergent process described in the action-centric paradigm of design thinking. In the built environment design, this conceptual phase is mainly attributed to architectural design where the solution of the architectural process represents the problem to be solved by the engineering methods. In this sense, the first half of the diagram represents the problem formulation process and the second, the problem-solving process. Only when the architecture or the concept of the solution has been set, the problem-solving engineering processes proceeds, converging toward the final solution.

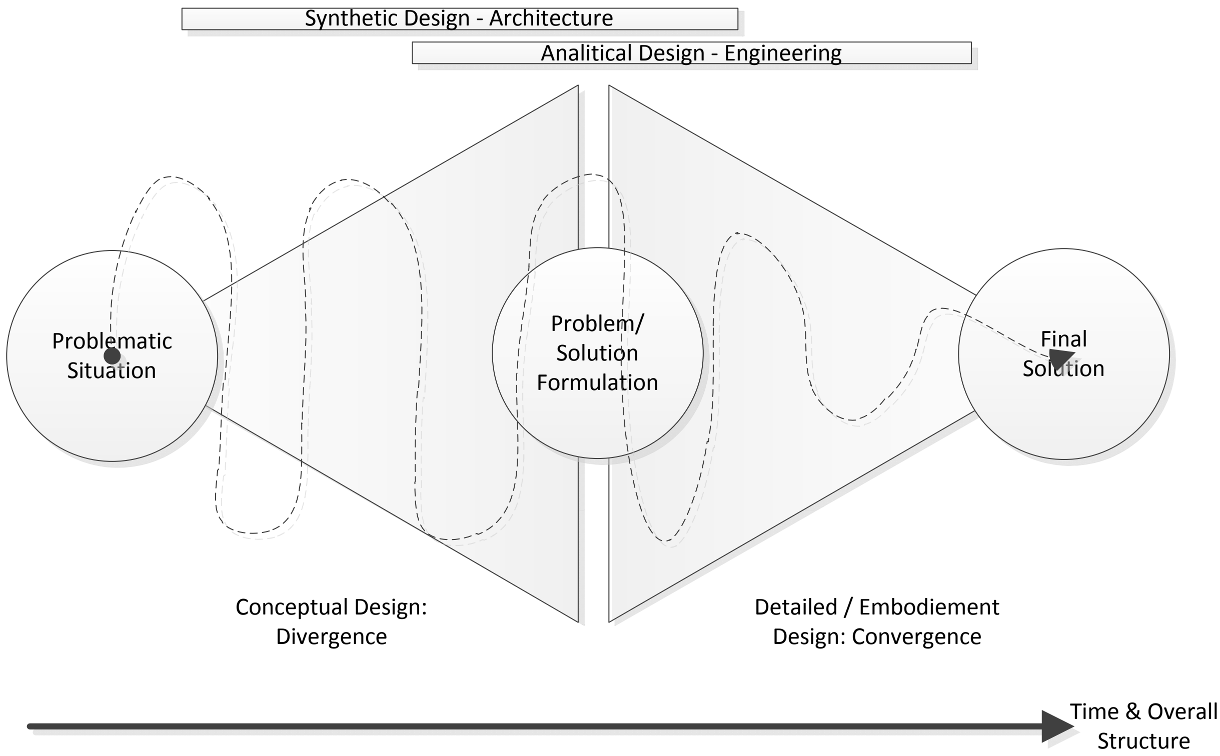


Figure 7: The envelope of the design process

The process-level representation only provides **an envelope** of the cognitive and social processes in design. The curved line inside the diagram represents the actual erratic processes of design in their divergent and convergent modes. Due to process-level interdependence, the direction of the design process at any given point in time is not possible to determine.

Another feature of the process level representation is the relative positioning of the architectural and engineering disciplines within the envelope. Although architectural design is traditionally attributed to the first half of the envelope diagram and engineering to its other half, it becomes obvious that the disciplinary boundaries should not determine the process. As in the architectural process there are parts of engineering of detailed solutions embedded into the overall concept, the same holds true for the engineering profession. Engineers develop conceptual solutions in the problem definition stage.

As a conclusion from the process level analysis of the built environment design process, two new terms can be introduced: **architectural engineering** and **engineering**

**architecture**. These two terms cover those aspects of their respective disciplines, which are not normally considered in discussions about the roles of the design process.

## 4.2 EMPIRICAL VALIDATION

### *4.2.1 Introduction*

To study the process-level characteristics of interdependence in design management, I chose to conduct an in-depth case study on a large infrastructure project. The aim of this section is to introduce results from this study in the context of validating the previously-derived theoretical framework. More specifically, this section elaborates aspects of design and solution domain interdependence (see subsection 4.1.3.1) as well as the temporal interdependence of adaptation and constraining (see subsection 4.1.3.2). This section takes a domain-independent perspective, although the findings are interpreted from the data obtained. The main contribution of the empirical study is to demonstrate the mismatch between the design management practices used and the nature of design. More specifically, it is to show that aspects of process-level interdependence are not captured by management approaches currently used in design.

### *4.2.2 Research Design and Method*

#### *4.2.2.1 Description of the Case Project*

The case project involved extending a section of a rapid transit urban railway system and incorporating it into the suburban rail system of a congested European metropolitan area. The scope of works comprised partial extension of tracks, replacement of track and signaling equipment, construction of four new stations and refurbishment of five old stations. The project was particularly demanding in civil works as 3.5 km of track is on viaduct and another 3 km is in tunnel. Besides the construction of a new section, the complete section needed to be upgraded to meet the national mainline standards. The design and construction were completed in two and a half years and the schedule itself consisted of roughly 16000 design and construction activities.

The public agency project owner undertook the contract under a contractor-led design and build scheme. The main reason for choosing this delivery method was that the project owner expected a single point of responsibility to better integrate the design, construction, and operation stages of the project.

There are several reasons why I chose a large infrastructure design project for analyzing interdependency in construction design. Firstly, the project was integrated in a way that allows a relatively fast pace with a possibility of overlapping design with construction. Due to the pace of such projects, many design activities are planned in parallel rather than sequentially, which causes additional fragmentation and complexity of the design process. Secondly, because such integrated contracts are undertaken relatively early and they are based only on the clients' requirements; there is an inherent uncertainty concerning the scope of the project. The deliverable dates, however, often do not change in such projects, which calls for a robust organization that is capable to adapt to sudden changes in scope and still deliver the job on time. Thirdly, the geometry and size of the constructed facility, along with the multidisciplinary contributions, accentuates the importance of design integration across numerous project interfaces. All these project properties highlight the need for tracing the interdependence and process in the design system to reduce consequences of uncertainty. An additional reason for choosing a fast track delivery approach was the political significance of the completion date (public opening). Therefore, owner-perceived advantages of a fast-track delivery method were the integration and collaboration between project contributors.

Figure 8 below depicts the design organization in the context of the overall project organization. The core project organization included the public agency owner and the contractor. Because the owner organization did not have substantial experience in railway construction, they appointed a project management organization to manage the project on their behalf. Concurrently, the contractor's organization mobilized an engineering department for the project with the aim of coordinating design and construction. The project also had three major external stakeholders, being representatives of the urban and the suburban rail systems as well as the operating company. The former two had the role of ensuring that the newly built section complied with the existing standards of both networks and the latter had the role to ensure that the delivered facility complied with their train operating procedures.

The design scope was organized in disciplinary *work packages* and geographic *design areas*. The disciplinary work packages comprised civil design, structures, buildings and services, mechanical and electrical systems in buildings, and design of accompanying rail systems (Fig 8). Each work package was further broken down into *design areas* defined as "geographical groups of neighboring work packages or a logical system comprising a number of subsystem work packages". Because of its fragmentation, the project developed an *Interface Management Plan* to identify and manage issues that would occur between work packages, design areas and organizations in the design supply chain. As the design evolved, the identified project interfaces were planned to be translated into requirements for each of the design contributors.

At the peak of the design, a total of around 600 of design staff were contributing to the project off site, which exploded the number of requirements to be handled. There were 6,000 requirements and about two thirds of them were changed or modified as the project unfolded. **These changing requirements were the key source of design management issues that this empirical study investigates**.

Around 1000 of those requirements came from the project manager as external requirements, while the rest were internal requirements created by the contractor's organization itself. The contractor's organization tried to encourage coordination by mutual adjustment between the teams to address the complex and intertwining links between the ever changing tasks. To facilitate mutual adjustment in the conditions of coupled remote and concurrent work, the contractor's organization used an online platform for keeping track of the changes. Nevertheless, even with the help of technology, coordinating large numbers of remote design teams was challenging. This was even more the case when different organizational contributions are mutually incompatible due to inconsistent management practices across different offices of a single firm. Each of the remote offices within would create its own requirements for the rest of the offices and synchronizing them by a common standard was time consuming and created tensions amongst the main designer's team members.

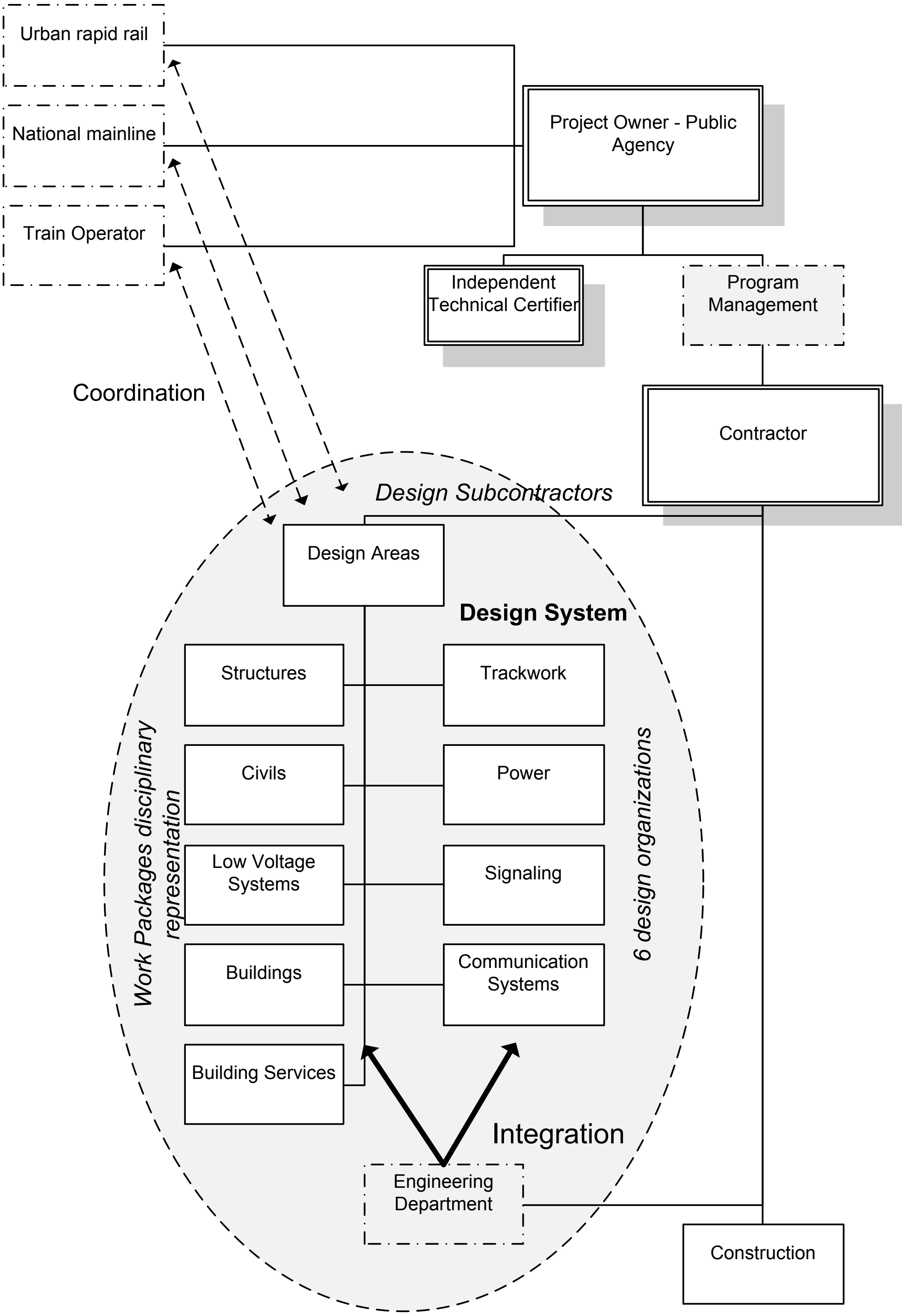


Figure 8: Organization structure of the case project

The flow of the design was planned as a two stage process: conceptual design and detailed design for the owner's construction approval. The project further fragmented the design process along those stages because the project management organization was supposed to produce the conceptual design work packages and design areas for the contractor's design team. The transfer of knowledge and assumptions made in the conceptual design stage would be transferred to the contractor's engineering organization before the detailed design production. During the detailed design production the lead designer and the contractor's engineering organization needed to ensure coordination via interdisciplinary design review meetings as the principal method of design integration.

The contractor had a web-based collaboration system in place to manage the requirements across different project levels. The high-level requirements would emerge from any of the project stakeholders, the contract, or other obligations with respect to technical standards and legislation. The contractor would then translate those high-level requirements into system-level requirements with such attributes as object type, work package, design area, and contract (see Fig 9). This structure should have ensured traceability of the requirements between the design team level and the project owner.

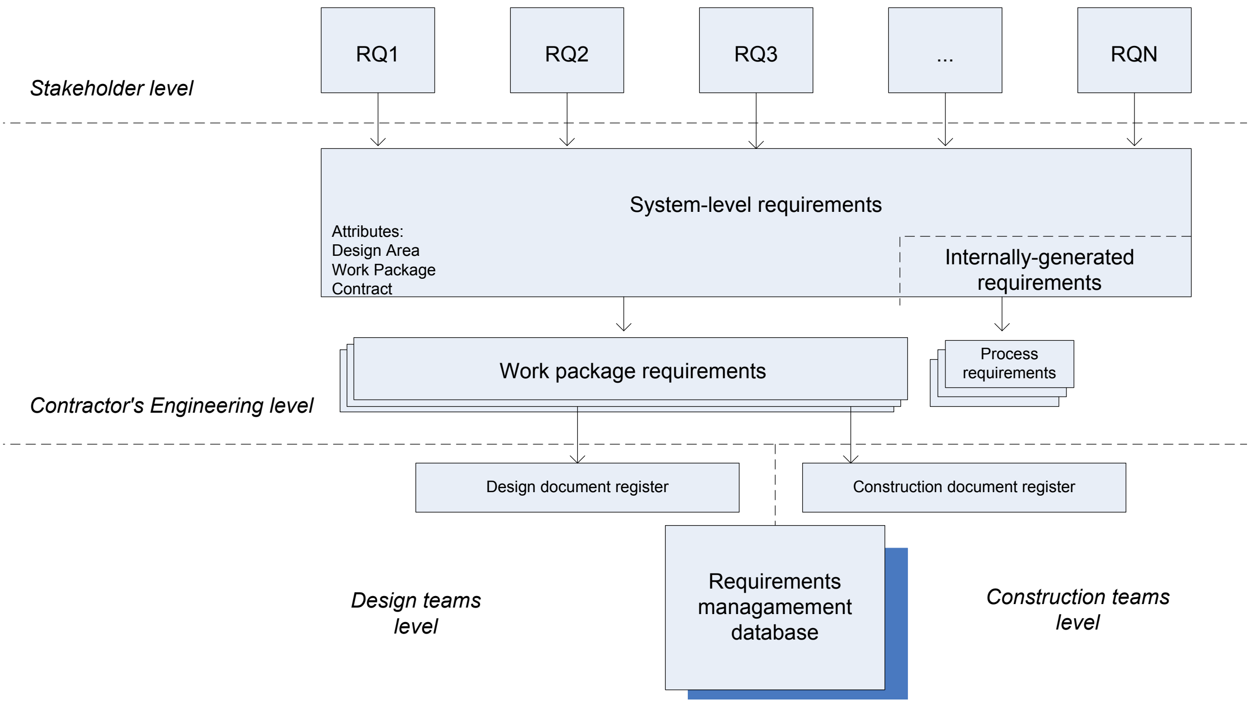


Figure 9: Requirements management system in the case project

This was the essence of process-level design management in the project as the design subcontractors were supposed to address the changing requirements and the role of the engineering organization was overall integration of the changes. The hierarchical structure from Figure 9, however, was not efficient as the fragmented design teams were addressing the requirements individually and the overall integration became problematic, as the following subsection will elaborate in more details.

#### *4.2.2.2 Sensemaking and Process-tracing Approach*

Although design is a creative mental process, it is still being conducted mainly in the context of economic organizations. In this case, the economic goals of this decision making process should not be forgotten. Designers aim to think about problems first and set up a course of action correspondingly. However, due to the cognitive limitations in the design process, the meaning of actions can in many cases be reached only through retrospection. This constitutes the paradox of design that states that, although actions need to be planned for in advance, the true meaning of the plan only becomes available when the full range of its consequences are known.

For these reasons, applying the retrospective sensemaking reasoning to design in the built environment appears to be particularly advantageous. The first set of advantages of this approach arises from the fact that taking an *ex ante* perspective would in a certain sense imply that the researcher knows more about the decision to be made than the decision maker, indeed, a situation that is highly unlikely to occur. Secondly, in a situation so complex and with so many participants, it is highly unlikely that all the decision makers are presented with the exact same information.

Following the positivist paradigm, contemporary scholars in construction project management (Winch and Maytorena 2009) contend that decision making in such highly-uncertain conditions, as the ones that appear in design, can be classified more reliably as *sensemaking* under bounded rationality than as rational economizing from traditional project management literature. Using the concept of sensemaking, as this section will argue, is a step forward towards describing the decision making process in complex problems of managing design in the built environment.

*4.2.2.3 Research Method*

To induce design characteristics, during a one-week stay in the project offices, I extensively interviewed five representatives of the owner's project management and the contractor engineering organization using structured and open-ended techniques. For the purpose of this study, only accounts by the contractor's engineering organization were further analyzed, thus setting the level of analysis to the contractor's system sensemaking. In contrast with the process maps as the result of the ongoing project, here the aim was to develop a cognitive map of the traced processes according to the managers' sensemaking and, finally, induce conclusions of theoretical validity from the single-case study (Eisenhardt 1989; Yin 2003).

Apart from fixing the interview framework to issues in the design management processes, the interviews were open-ended, allowing the subcategories of the topic to naturally emerge during the one-hour long interview interactions with each informant. This unstructured interview setting informed this research about the scope of the complex inter-organizational arrangements in the supply chain and their influence on design. I triangulated the data obtained from the interviews with relevant internal project documentation (project reports, schedules, organizational diagrams, etc.) and with publicly available material from press coverage of this public-funded project. After having analyzed the data from open-ended interviews and project documentation, I then carried out two follow-up telephone interviews that were structured around several topics identified in the initial research session. The aim of the follow up interviews was to get more in-depth information about specific instances of design issues. Following the open ended and structured interview sessions, this section induces theory by tracing the processes of how the project design was unfolding in an attempt to establish causal relationships between the events and their consequences occurring in the project (George and Bennett 2005).

In summary, the following part of the thesis will draw from micro-level findings in an attempt to provide a descriptive interpretation of design task interdependence and process. The direction of theory-building, as mentioned in the introduction, is from the micro-level of design task to the macro-level of design organization that will be elaborated subsequently. The logic of theory building in this thesis is thus to first describe distinctive characteristics of design and to develop an appropriate theoretical management framework afterwards. The following sections elaborate and discuss findings from the case project in the light of previously introduced theory on design methods.

### *4.2.3 Hard Complexity: Problem and Solution Interdependence*

This section will present findings from the case study in the light of the theoretical framework from subsection 4.1.3.1 that considers the co-evolutive process of design problem and solution. First, I present several instances of problem and solution co-evolution accompanied with informant quotes. I then present a project story that incorporates aspects of problem and solution interdependence followed by a discussion.

#### *4.2.3.1 Instances of Problem-Solution Co-evolution*

In reconstructing the design management story from the perspective of the contractor's engineering organization, complexity of interdependence in design tasks was immediately obvious (all quotes are retrospective interpretations by the engineering director).

> *"These things can have all sorts of little strings that are going to go all over the place. And it's just one of those things that happen. You're working through a particular issue and all of the sudden you find that it is going to cause a horrendous situation."*

The design of the project faced unforeseen complexity in a number of situations that led to different outcomes. In some cases, the requirement was simply deleted:

> *"Another requirement at yet a different station is that the design team needed to provide passive positions for external escalators. The problem was that they didn't own the land. In the end, the client again decided not to go down that route and to leave out that aspect of the design. This, in turn, allowed the design team to delete the requirement for the provision of the power for those two escalators. This made an enormous difference because the local power supplier wasn't able to provide enough power for those two escalators. To do that, they would have had to spend over a million pounds, and it would have taken him, he reckons, three years, to get this additional supply into the station."*

In other cases, implementing the requirement was the only option and the engineering organization was responsible for implementing the requirement at their expense.

> *"In other cases, we had to bite the bullet and spend the money. In one location we had to buy some additional land to be able to fulfill that requirement. There was a fire safety requirement that high voltage cables should be run separately, so that when one cable blows up, it doesn't take the other with it. So we had to run the cables along this extra land that we bought and it was a considerable problem. This was not considered in the conceptual design stage. They just thought: they will be able to sort it out.*

These three instances all show the hidden interdependence in the project that hindered the implementation of changes into the project system. The complexity resulting from this interdependence was not included in the project management procedures that only describe the hierarchical decomposition of project structure. Therefore, at the outset of the project, the design process was structured in an overly simplified way that did not predict well the implications of changes on the entire design process.

#### *4.2.3.2 Project Story*

I continue with a more detailed description of how the above introduced seemingly small project requirements played out a significant role in the project. Figure 10 below depicts the traced process of a situation, in which a seemingly simple requirement amplifies and propagates through the project due to complex interdependence.

The traced process begins with two requirements simultaneously being introduced by the client and internally within the project team. The client's requirement was that design team provides a possibility for subsequent installation of an external escalator in one of the stations. The passive provision for an external escalator, however, required that additional power be supplied to the stations and, in turn, the entire section. More power meant that thicker cables had to be arranged for its supply. Thicker cables meant a higher volt-drop and, consequently, further increased the demand for power in an interdependent loop that caused a substantial amount of the power systems to be redesigned for this sole purpose.

Redesigning the power systems caused a requirement for additional space to accommodate the newly designed systems. This space, however, was not available neither in the station that had already been designed by that time (and, in other instances, also built), nor in the form of land along the tracks. Therefore, additional land had to be acquired to run the cables along the section, and the buildings had to be redesigned with the new space requirements. It caused another iteration loop in the design that led to subsequent design integration problems due to geographically-distributed organization of the design process that was the main designer's choice.

Roughly at the same time, a second requirement emerged that needed to be implemented. It related to fire-safety as a consequence of implementing the fire-safety regulation into the design. The implementation of this requirement, in turn, caused an even greater demand for power and, consequently, more land to be acquired to run the additional cables along the tracks. When combined, the total amount of power that was now required for the section became so large that not even the local power supplier was capable of supplying it.

These requirements, however insignificant they may have seemed at the time when their implementation was decided upon, caused extreme consequences for the project. In this example, the insufficient local power supply, these difficulties were insurmountable and resulted with rejection of the requirement for passive provision of external escalators.

*4.2.3.3 Discussion*

On the basis of the findings from the case project, I will compare the hierarchical decomposition, as an anticipated project structure, with the causal structure, as a result of retrospective sensemaking of the project (Fig 10). The requirement management procedure was a hierarchical structure that linked requirements to discrete and abstract entities such as work packages, design areas, and contracts. The relationships between the requirements and work packages and other elements were on a one-to-one the basis. In practice, however, parts of the system have not proven to be manageable in discrete pieces and such bilateral dependencies.

Instead, the overall system exhibited intricate internal interdependencies between the subsystems. For this particular situation, the cognitive process-tracing map shows three distinct design subsystems: power systems, buildings, and planning with land acquisition. Besides the overall design iteration loop, these design subsystems performed additional iteration loops within themselves.

The co-evolution of design problem and solution is obvious in this example as the design problem and solution changed domains several times during the problematic design situation. More specifically, the domain changed from power systems to building design to planning and land acquisition. And finally, the problem domain left the design system into the design environment.

Although it cannot be said that this example captured the soft aspects of design, the behavior of the overall system was highly non-linear in that, due to the system complexity, a small change caused a tremendous impact to the overall design. The scope-level interdependence in this example was a knowledge problem and could have been predicted by using a different kind methodologies based on cause and effect diagrams. Theory suggests that this problem could have been mitigated by using system dynamics (see subsection 3.2.6.7) and causal loop diagrams that could have predicted the chain of events unfolding as the consequence of the requirement that was supposed to be introduced into the system.

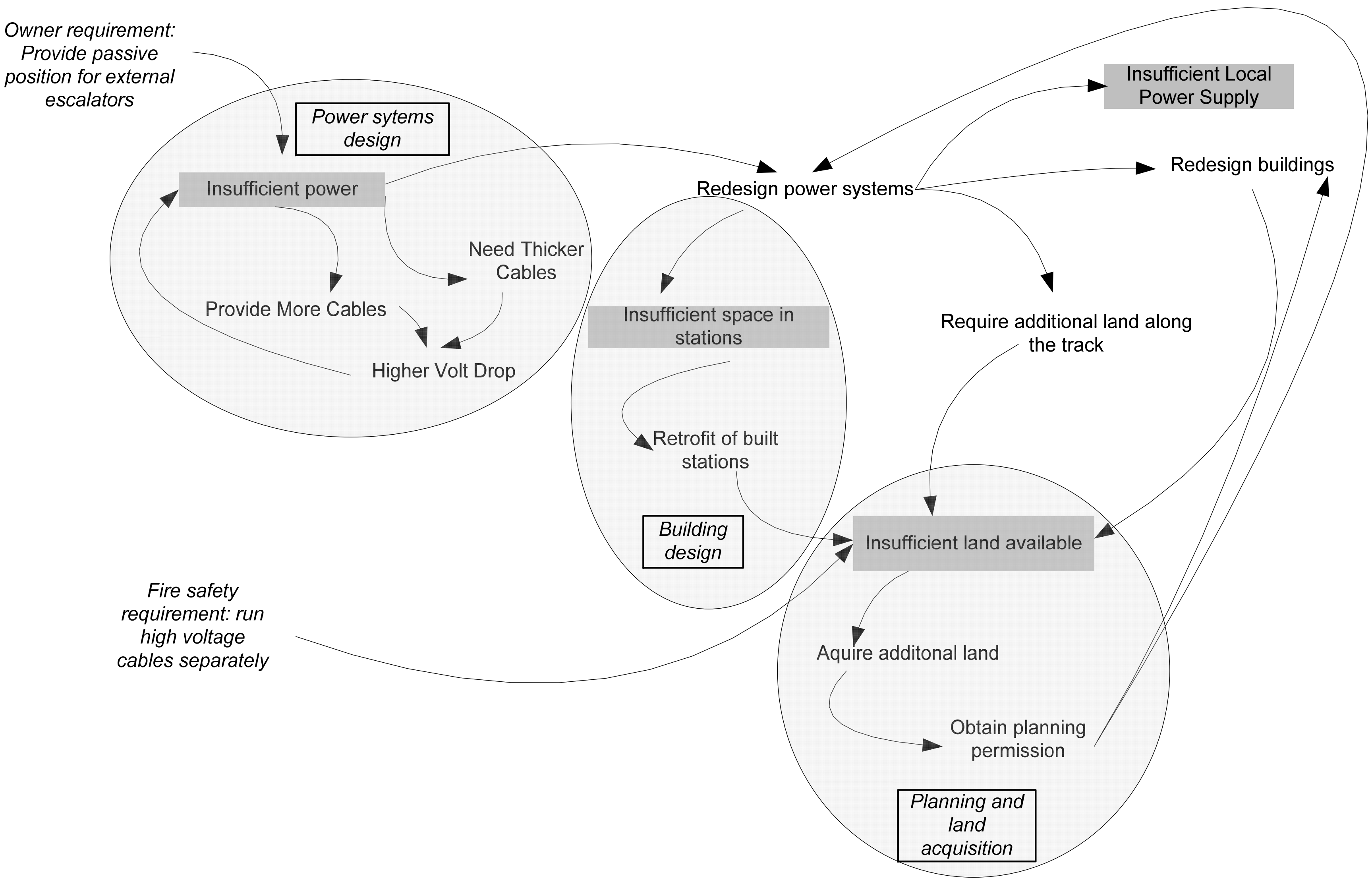


**Figure 10: The process-traced sensemaking of hard interdependence in the case project**

### *4.2.3.4 Relation with Soft Interdependence*

In this discussion, the problem and solution domain interdependence issue was at the level of complex problem-solving, rather than soft systems. In the case of soft system interdependence, it would be much more difficult to propose a simple solution for this problem. In this example, the only reliable way for me, as an external researcher, to identify interdependency was through ex post interpretation rather than any other kind of assessment. This scenario is, however, not realistic as a project structure should have already been established when project went into its execution.

This implies that the "hard" planning process needs to take into account "soft" events that are outside the realm of planners' cognition and understanding of the project context, a paradox not unlike the very concept of wicked problem solving. As a result, the question is how to plan for solving of problems, which are beyond comprehension in the planning stage.

As a consequence, a host of questions come to one's mind. For instance, how does this interplay between the rational decision-making in hard systems and ambiguity in soft systems occur? On the one hand, every decision needs to be rationally argued for. On the other, however, these decisions also need to take into account the condition of bounded rationality that, by definition, constrains their validity. When these decisions have an economic impact on the project budget and organization, this rationale becomes even more complex. How to argue for budget that will cover all the possible contingencies during the collaborative problem-solving of design?

Although I cannot offer a compelling answer to these questions, I do believe that being aware of this organizational paradox is of key significance for design managers. To mitigate this problem, design managers can choose one of the following strategies: either to use a very similar structure from project to project, or incorporating significant buffers into their plans. Both of these strategies, however, have their shortcomings. While the former hinders innovation and creativity by turning the product development process into a repetitive effort more similar to manufacturing, the latter strategy risks significant budget and schedule overruns and, as such, difficulties in negotiating the requirements with the client.

The following section is dedicated to this issue. It will elaborate findings from the case project in the light of working with preliminary information, a situation that creates a number of soft links in system interdependence.

### *4.2.4 Soft Complexity: Working with Converging Information*

The execution of the official design management plan faced numerous coordination issues in the case project. The complexity and size of the project scope along with the chosen task subdivision strategy caused temporal conflicts in the form of unforeseen design iteration loops and numerous change orders from within the integrated process. This section will take the theoretical stance from subsection 4.1.3.2 of this thesis, one that considers the process of design in terms of information exchange between the design tasks. Under this light, this section analyzes design management in the case project as exchange of preliminary information and the timing of this exchange. This section then elaborates sequential and concurrent design strategies as two possibilities of the design process. The issue of working with preliminary information has provided a basis for a long-lasting debate on the advantages of concurrent design approaches in the built environment.

#### *4.2.4.1 Instances of Adaptive-Constraining Interdependence and Preliminary Information*

There were several instances on the project where finalized information caused problems for the subsequent design. This is an illustration of the adaptive-constraining features in design that caused significant problems due to the complexity of the project.

> *"The design that you create in the early phases will generate requirements on later design. In civil design, for example, we were making assumptions that would influence designs that hadn't even started yet (C)."*

On the other hand, information used in concurrent decision-making is preliminary by nature. In terms of the precision/stability of information, I coded several instances of communication being communicated in an unstable way, therefore causing significant rework. The reason for communicating preliminary information is the multidisciplinary nature of the design process.

> *"Design cycles are different for different disciplines. They need their information at different times (PM)."*

The effect of preliminary information on the design process was iteration and even retrofitting of built structures. One example of how different stages of detailed design influenced each other is a situation where several buildings were designed without sufficient allowance to accommodate different systems which were being designed later.

> *"They designed the buildings fairly early on and we'd had it built and then they would find that the switchgear didn't fit the room properly, or the cables were thicker than they thought and more of them… (PM)"*

In the above example, the constraining features of early design phases had such a strong impact on the subsequent design tasks that the solution space was reduced dramatically. It is a consequence of the sequential relation between design of different railway sections and their buildings and equipment.

Designing the station buildings was a technically demanding task because different engineering systems had to integrate in any given building. In this case, the problem was that earlier design did not take into account the rate of development of subsequent design. Generally, the interface between the civil works level of design and the rail systems level was not sequenced appropriately.

> *"We should have probably started designing the systems earlier. At the coordination meetings, the systems designs weren't far ahead enough to know what the requirements on the buildings would be (PM)."*

Finally, due to delays in the design review and approval loop for some parts of the design, the contractor was forced to take the risk of starting the construction with incomplete design information. Namely, due to delays in the design review and approval loop for some parts of the design, the contractor was forced to take the risk of starting the construction with incomplete design information.

> *"Just to get things going on the site, we had to cut across some of the formal procedures from PM. Design was simply taking too long to get approved. If we would assess the risk to be acceptable, we would go out and build it at our own risk (C)."*

During the design-construction overlap in non-approved design tasks, the contractor was addressing comments from the formal approval process directly on the construction site by improvising. Simultaneously, the design was going through its third or fourth round of iteration to address those comments. In some cases, minor rework on site was necessary to take into account the design changes.

> *"They had to drill some holes in precast walls and ceilings to allow for cables to pass through (PM)"*

Indeed, in the case project, design managers were making sense of construction rework due to design preliminary information as being a normal part of the design process as the following quote demonstrates.

> *"Constructing without the approved designs was not the end of the world. Those are the things that you can manage well and not so well. On fast track contracts, things happen. When you're building quickly behind the design and before the design is finished, then these are the problems you get (PM)."*

Regardless of the distinction between finalized and preliminary information in a current design cycle, in certain instances nominally finalized information was changing. When design was going through multiple iteration cycles in the approval loop, oftentimes this implied changes on previous design and affected requirements for subsequent design. In every design iteration, there might have been a possibility of redoing some information and refreezing it back. I found evidence that the possibility of communicating in terms of intervals might have been possible in the project. This, in turn, might have reduced the problems associated with rework.

> *"If systems design had started earlier, the main designer would have known their requirements on the buildings. The systems design should have given a sort of an upper envelope of what their requirements might be for the civil design. (PM)"*

This informant articulated the logic of **communicating by intervals instead of fixed values** which is the first **condition for developing sets of solutions**. The second condition is the existence of a discrete number of natural sets that can be identified. Again, I found evidence **that a set-based reasoning might have been possible**.

> *"In railway design, the power systems come towards the back end of things. That is, pretty much everything you do in design will have its impact on power. So in one case, the client came with a requirement to install a specific type of a system and that caused enormous problems with power. We needed to redesign a quantum leap stronger system."*

Since the requirement came externally, it could have not been predicted by the project team, thereby classifying the problem as ambiguous instead of uncertain. Nevertheless, due to standards and the design practice, a specific solution existed to comply with this requirement (i.e. an order of magnitude thicker cables, etc.).

*4.2.4.2 Project Story*

To corroborate the above evidence for the existence of soft links in the design process, I present a situation from the case project. The situation concerns how the design process occurred in practice and the issues arising from working with preliminary information. As mentioned in subsection 4.2, the design process was taking place in a sequence that followed the geographical division of the designed railway section. For instance, design area 1 would first be designed and, while the designers were working on the following design area, construction works would already have commenced for the preceding area. This logic is common in design-build arrangements as it allows for design and construction activities to occur simultaneously, albeit with a geographical and temporal delay.

Figure 11 gives a representation of the design process. It depicts two bundles of design tasks, for two geographical areas of the project. The first bundle of design employs the design supply chain consisting of a number of design subcontractors who contribute to the work packages in the designed geographical area. They worked with preliminary information and integrated their contributions through design review meetings. In this situation building design and civil engineering preceded the construction phase of the first design area. Because at the beginning of the design effort, all the values could not have been assessed, the designers worked with preliminary values concerning electrical power systems. These preliminary values were used in the design of station buildings that have subsequently been built.

As the design proceeded to the next geographical are, the input for design of electrical power systems was slowly converging to values much higher than initially envisaged. This increase was a **soft issue** because many of the requirements that were arising during the design process could not have been predicted in advance. Due to this increase, however, it was found that the stations, already built in the previous geographical area, were not large enough to accommodate the equipment. This created substantial constraints on the subsequent design and procurement phase as only one equipment producer could be found that could offer that size of equipment.

*4.2.4.3 Discussion*

The previous example demonstrated how, because the design build arrangement assumed construction on the basis of preliminary information, advantages of the concurrent process employed in this project were very limited. This is a clear evidence how uncertainty caused by preliminary information represents **soft interdependence** in the design system.

This soft interdependence was a result from the exploding number of additional requirements that were produced as a consequence of the concurrent strategy. In this strategy, design was constructed collaboratively, with each contribution discussed in terms of how it constrains other individual contributions as well as the overall solution. For this reason **internal constrains were emerging**, causing the design process to undergo its second, third, etc., iteration cycles.

The iterations continued until the design solution has converged to an acceptable state of alignment with external and internal requirements. The generated design information were subsequently frozen and transferred to construction and subsequent design stages as finalized information. Future design therefore, was going to adapt to this information and additional requirements from the project environment. In such a way, the design process was bound to two levels of iteration and convergence: the internal level of design bundles and the overall level of the process. Cases where the construction of the designed area was scheduled immediately after its design are the best representations of finalized information.

There were, nevertheless, other instances of the process where design needed to reiterate the finalized information, thus the unfreezing and refreezing back project information, similarly to what Whyte et al. (2007) have observed in design teams. The best such example was the retrofit of a station building because problem solving in subsequent stages of design generated new requirements for the sections which had already been built.

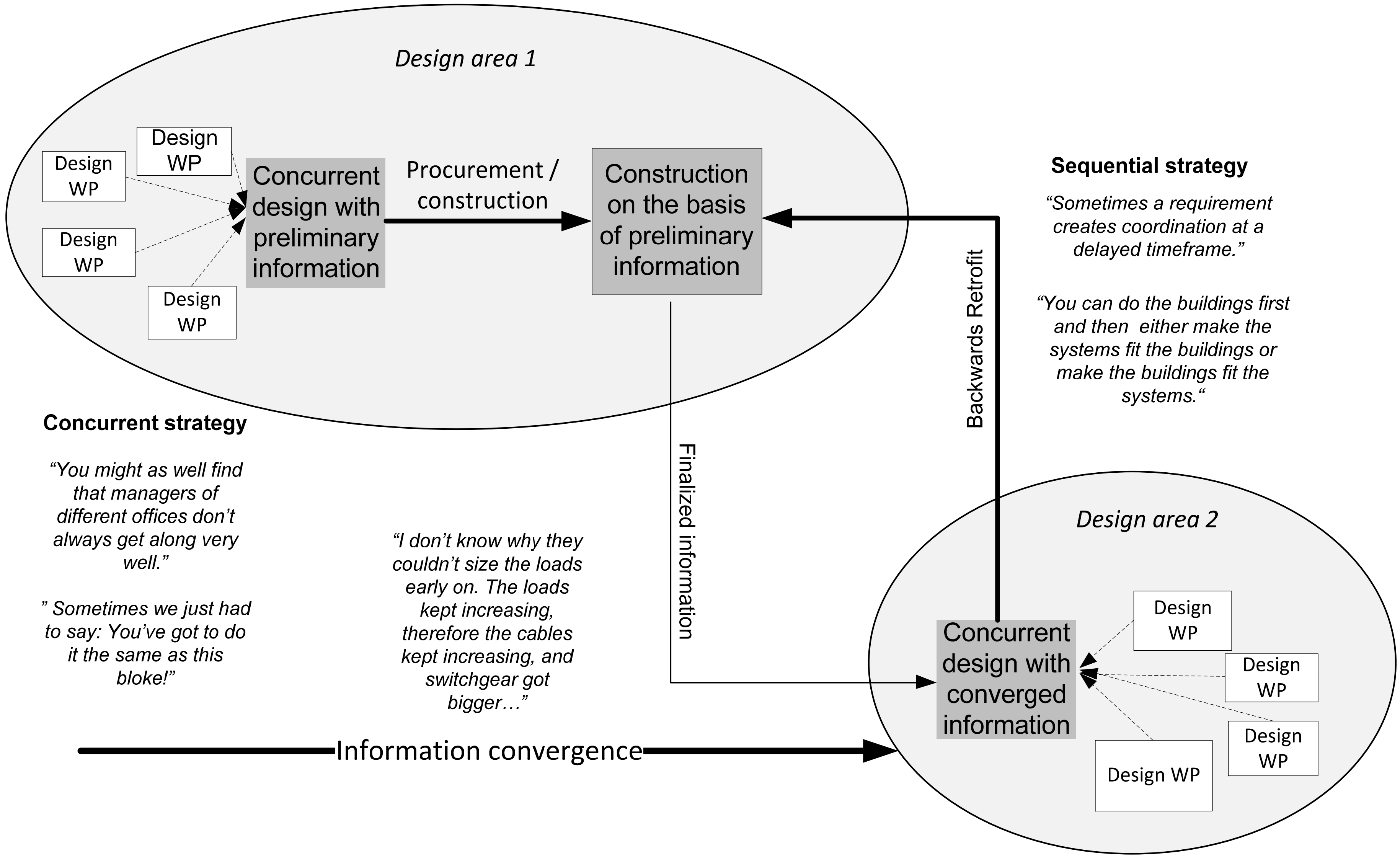


Figure 11: Cognitive map of soft interdependence in the case project

## 4.3 CONTRIBUTIONS AND RECOMMENDATIONS

### *4.3.1 Theoretical Contributions and Suggestions for Further Work*

Elaborations of design interdependence transfer concepts from general design theory into the realm of the built environment design, thus making a contribution to design methodology. The study on hard interdependence extends the co-evolution concept in design (Maher 2000; Dorst and Cross 2001) with an application to the realm of infrastructure design. The study on soft interdependence uses theoretical concepts of information flows in new product development literature (Cross 1993; Pahl et al. 1996; Krishnan et al. 1997; Terwiesch et al. 2002), to accomplish a better compatibility between the process stream (e.g., Halpin 1993; Kagioglou et al. 2000) of theory and the concurrent engineering toolbox in the field of construction design (e.g., Anumba et al. 2002; Bogus et al. 2005). In construction, an industry traditionally focused on managing outputs, such attempts would integrate different production aspects in a way that is represented by, for instance, Koskela's (2000) Transformation-Flow-Value view. We, therefore, believe that descriptive studies, such as this, have a significant potential as a basis for future research.

And finally, the results of this study also have a significant potential to upgrade the existing design management toolbox (e.g., Austin et al. 2000; Kagioglou et al. 2000; Ahmed et al. 2003), the toolbox of integrated project delivery (AIA 2007), and concurrent engineering (Anumba and Evbuomwan 1997) with a normative set of recommendations that can be used for organizing the integrated delivery process.

Based on elaborating the two types of interdependency, I envisage **two individual streams as continuation of this research.** The **first** stream would be focused on **hard interdependence**, advocating the use of system dynamics and similar methods based on loops of cause and effect in complex technical systems. The **second** stream would be basically of social-psychological nature and would **address the soft aspects of interdependency** that occurs in systems comprising human agents. This second stream would mainly draw from cognitive psychology and social science body of theories and methods, such as, for instance, the **sensemaking concept**.

### *4.3.2 Practical Recommendations*

On the basis of the theory derived and findings from the case study, the key question that design managers will ask is: **How does it help us to manage design better than we currently do?** This chapter will attempt to categorize the practical implications of this research into several practical recommendations.

Although they constitute the basis of most project management systems, work breakdown structures based on simple hierarchies of linear dependency are not sufficient to subdivide a complex design problem. Such problems should be subdivided based on interdependencies between the systems that exhibit complex behavior. This means that thinking in terms of cause and effect would be more appropriate than the traditional hierarchical thinking.

***Recommendation 1: Managing design is learning about the project.***

The most important implication for process-level design management is the notion on design interdependence that requires the continuous learning process to understand the intricate reciprocal relationships in the design system. This means that the design managers should adopt the learning mindset instead of the execution mindset that is oftentimes advocated in classical project management literature.

***Recommendation 2: Think of design in terms of systems instead of linear breakdown structures.***

Thinking in terms of systems is advantageous because it facilitates:

- Setting the scope of interdependence domain space. As the co-evolutive concept of design problem and solution demonstrates, the domain of problem-solving will exhibit leaps as new requirements arise for ongoing design (see 5.3.1 and 6.4). The best advice to address this problem would be to replace the linear work-breakdown-structure-based reasoning with a *system dynamics* way of thinking that introduces the causal link between the different design systems. This will, by no means, tame the wicked nature of design but, at least, it will set the domain of task interdependence from the disciplinary level to the systems level.

- Communication and collaboration in design. Since design is a cognitive process of socially constructing project information, the key issue is to negotiate the goals of the project and metrics of success. Aligning the stakeholders' interests into a congruent set of project criteria will help lead the design process and reduce organizational friction between members of the project coalition. In extreme cases, iterative loops of rework can become so frequent that project teams need significant mutual trust to avoid the failure of the project due to what Weick (1993) calls the collapse of sensemaking.

Applying the systems thinking paradigm, especially in the form of system dynamics modeling tools, would be the first step towards a better representation of design for at least two reasons. First, this study anticipates that having any kind of a systems-level mental representation of design will contribute to consensus-building within the design teams. Because different disciplinary contributors use different mental models in their reasoning and, most of the time, they are limited in understanding the implications of their decision on the rest of the designed systems. And secondly, this study has shown that much of the perceived "wickedness" would very easily have been tamed just by using a simple qualitative systems-level model based on causal loops of interdependence between the designed and designing subsystems.

***Recommendation 3: Reduce the scope of interdependency through modularization.***

Modular design techniques aim to subdivide complex systems based on a number of relatively independent design modules. Modules are developed with the main goal of weakening the interdependence between tasks so that downstream becomes less sensitive to changes in the upstream. In this way, the need for communication between the modules is reduced. There are several ways to achieve a modular design structure:

- Overdesigning is the most obvious strategy to weaken the interdependence and therefore create design modules. Such modules are much more resistant to changes in the rest of the system and less prone to iteration.

- Set-based design assumes the existence of natural sets of discrete solutions in the scenario-based-planning line of reasoning. When several discrete design options exist at a certain point of the design process, all of those options should be elaborated. This saves the design managers the time of rework as one of the design options will be adopted in a relatively detailed stage. The cost of set-based design is duplication, but its advantage is focus on the convergence of the design solution.

The remaining modules should be considered as stand-alone units and, as such, they should be integrated at the process level as their separation would lead to excessive costs and the need for communication.

***Recommendation 4: Execute the design modules with internal interdependence in an interdisciplinary, collocated, and iterative manner.***

Interdisciplinary execution implies the concept of concurrent design, collocation implies establishing a physical environment where social interactions take place, and iteration acknowledges that rework is a natural consequence of ambiguity in design.

- Interdisciplinary design simultaneously involves a variety of design contributors who collaboratively negotiate towards a design solution. Although each of the design disciplines is trained in achieving the local optimum within the corresponding domain, this does not imply the best solution at the systems level of overall design. Design teams should therefore engage in an interdisciplinary collaborative effort of negotiating the “global optimum” for the design problem.
- Collaborative design is only possible through mutual adjustment at the level of the team. This implies that the team should be socially-coherent. I suggest collocation as one way of achieving this coherence as it requires the individuals to align themselves with the organizational culture of the team. Although I do not claim that team collocation a sufficient condition for efficient team performance, one of the recurring claims by the informants in this study was that such mutual adjustment is more likely to occur in a collocated social context than in a dispersed context.
- The iterative design method has been long established in the facility design sector. One solution is elaborated and iterated for as long as it has reached an acceptable state of alignment with the requirements. This method is the only choice in the case

of high ambiguity, which occurs when not all the influencing variables of the design process can be envisaged. The cost of the iterative method is the possibility of the design process becoming divergent, with an indefinite number of iteration cycles. When the design process goes divergent, it can only be stopped when the team runs out of time or budget, even if the state of design solution is still far from optimized.

***Recommendation 5: Integrate design modules at the process-level, not at the contractual level.***

Although the advantages of contractually-integrated project approaches clearly exist, such approaches do not guarantee integration at the design process level. In fact, when contractors take responsibility for the entire project delivery, there is a realistic possibility of introducing an additional level of subcontracting that can be difficult to integrate into the project. Such a poor structure of concurrent design will create unforeseen interdependence that can ultimately lead to significant rework of the concurrent task package. One such example would be backwards retrofitting at the interface of design and construction (see subsection 4.2.4.3).

***Recommendation 6: Use soft skills to juggle between sequential and concurrent strategies of design.***

Although this recommendation may seem vague, the case project exhibited situations of soft interdependence that cannot be articulated with the available problem-solving knowledge. Instead of forcing the concurrent decision making continually, there should be a balance between the individual decision maker's autonomy and the consensus-building in collaborative decision making. An exact recipe for achieving this still does not exist and success will depend on given social-psychological circumstances of the design team and overall project as well as on the design manager's social skills.

## 4.4 SUMMARY

This chapter extracted the theoretical basis for analyzing the process-level of the built environment design management in a domain-independent way. Departing from the theoretical paradox between the hard and the soft streams of design thinking, the chaper elaborated design interdependence as the main obstacle to integrate the hard and the soft streams of design reasoning. Design interdependence is elaborated in from the perspective of its scope and temporal relationships. Based on the process-level elaborations of interdependence the chapter proposed a process-level envelope of design that integrates the problem-solving and the action-centric streams in a theoretical framework that depicts the overall design process as a divergent and convergent interactive intellectual effort. One feature of the envelope representation is that virtually all the design methods belong to the problem-solving domain, whereas there is a lack of methodology to support the problem definition part of the design. The other feature is the mismatch between the disciplinary concepts of architecture and engineering and the roles of the design process.

By using case-based evidence, the chapter then validated the descriptive framework derived. in this section. Case findings corroborate the idea of decomposing the wicked problem into components of soft and hard interdependence and using the available methodology accordingly. Although design issues with hard interdependence can be resolved by using systems thinking based methodologies (i.e. system dynamics), soft interdependence can only be tackled by design managers who have the appropriate social skills. A number of design organizations are beginning to recognize the need for soft skilled design management in a transition from project management to project leadership. The soft-skilled design manager possesses the ability to coordinate the design process that is informed by preliminary and converging information. This can only be accomplished with a skilled strategy of pooling and separating the decision-making in the design process by employing a combination of sequential and concurrent strategy.

Firstly, pooling design tasks for concurrent execution increases flexibility of the design process as a whole, but it also increases its complexity, because the number of requirements to handle might become almost impossible to manage. Secondly, managers might choose to sequentially separate different parts of the design process, thereby reducing the number of parties simultaneously involved in the process. With this mode of execution, fewer requirements will emerge on the agendas of concurrent coordination, while the developing design will be transferred as a set of requirements for subsequent stages of design.

The chapter concludes by extracting the theoretical contributions and practical recommendations that emerge from the process-level study.

# CHAPTER 5:
# PROJECT-LEVEL DESIGN MANAGEMENT


**Abstract:**

Chapter 4 of this thesis assembled and validated a theoretical framework for process-level design management. The main finding at the process level was the existence of complex interdependence that is not taken into account by traditional management methodology. Because of this, in Chapter 4, I argue for the development of **more interpretive design management methods** that would take into account the identified soft and hard aspects of interdependence. The main conclusion from the process-level of analysis is that, unlike production project management, **isolating the design task should not be the focus of design management**. Because design behaves as an interconnected system of events, management based on decomposition into discrete elements is not applicable. Although very little can be said with certainty about the process-level of design, it becomes clear that using prescriptive techniques for planning and control would actually hinder the natural flow of the design process. Instead, as Chapter 5 will propose, project-level design management should be based on a more flexible management concept. This chapter will identify this approach as the **management of design expertise in terms of knowledge transactions instead of classical resource allocation**.

## 5.1 BACKGROUND: DESIGN EXPERTISE AND ECONOMICS

### *5.1.1 Introduction*

The previous parts of the thesis have demonstrated that the hierarchical decomposition techniques are not effective for design management. This is the case because the design task, the central object of project management techniques based on neoclassical economics, cannot be isolated and viewed independently. Following the process-level theoretical view on design from the previous chapter, the present chapter will introduce a project-level organizational dimension into the discussion. With that in mind, the following question arises: How to represent and manage design at the project level?

To answer this question, I will recapitulate conclusions from Chapter 2 that identified design as a cognitive activity with socio-psychological and techno-physical determinants. It is, therefore, a knowledge-intensive sector. Because of this characteristic, the main goal of this chapter is to argue that the central feature of design management is **design expertise that corresponds to individuals with knowledge that is needed to deliver the task.** The role of professional expertise is crucial because design is a setting that fails to exhibit a clear boundary between neither the problem and the solution, nor the upstream and the downstream of the process.

This chapter, therefore, will elaborate categories of expert knowledge in an attempt to better understand the nature of expertise as the main resource of design management. Secondly, this chapter will address the topic of design economics, by and land large underrepresented, if not entirely disregarded, in the discussions on design management. This chapter will then integrate the expertise with economics in a section on talent management in design organizations. Finally, the chapter concludes with establishing the need for the further development of project-level design management body of knowledge that is based on design expertise and the economic aspects of its management.

### *5.1.2 Composition of Expert Knowledge*

Schön (1983) illustrated design expertise by comparing it with jazz improvisation in the following way:

> *"When good jazz musicians improvise together, they also manifest a "feel for" their material as they make on-the-spot adjustments to the sounds that they hear. Listening to one another and to themselves, they feel where the music is going and adjust their playing accordingly… Improvisation consists in varying, combining, and recombining a set of figures within the schema which bounds and gives coherence to the performance. As the musicians feel the direction of the music that is developing out of their interwoven contributions, they make new sense of it and adjust their performance to the new sense they made. They are reflecting-in-action on the music they are collectively making and on their individual contributions to it, thinking what they are doing and, in the process, evolving their way of doing it."*

If design expertise consisted in only explicit knowledge, computers could easily be programmed to conduct the problem-solving and decision-making. Managing design expertise is therefore managing different categories of knowledge as Cook and Brown (1999) summarize:

> *"We hold that knowledge is a tool of knowing, that knowing is an aspect of our interaction with the social and physical world, and that the interplay between the knowledge and knowing can generate new knowledge and new types of knowing."*

Why is, nevertheless, the phenomenon of expertise such that experts cannot be managed at the process-level effectively? The complexity of expertise, as this section will demonstrate constitutes categories of individual and social components of such expertise.

#### *5.1.2.1 Individual Domain-specific Expertise*

When someone is considered an expert in a field, this is normally an indication that the person possesses **individual domain-specific knowledge** that he or she acquired as a structured effort over the course of a number of years.

*"Design seems to be an activity that requires a certain level of maturity to be practiced well. To qualify professionally in architecture throughout the EU now takes about 8 years on average. Most product designers will have studied for 4 years and many for 5 or 6 if they have done a master's. For a designer to be known individually by name in these two fields before the age of 40 is exceptional. By contrast, mathematicians and scientists in research universities are expected to have made their major contribution well before this age. Many good musical performers and virtually all successful sportspeople are likely to be similarly youthful when achieving their reputations. This already hints at one characteristic of design expertise. It is to a significant extent dependent on gathering experience."*

This is how Lawson (2004) introduced the issue of expertise in design. Design firms summon a pool of individual expert practitioners whose knowledge is idiosyncratic and specific to a design task. Since the **design task by definition is not precisely defined**, the expert designers will both frame the problem from the perceived situation and offer a solution for the problem by using their idiosyncratic design knowledge. This means that the expert's contribution will be as unique as the psychological frame, from which he/she approaches the problem. This also means that the designer will attend to the problem by framing it from the perspective of his/her expertise educational background, and culture.

Lawson and Dorst (2009) describe the process of acquiring expertise by using the analogy of playing a musical instrument:

*"The novice flautist then plays a scale in a very halting and deliberate fashion imagining which note must come next and then forming it… The flautist could see such an arrangement in the mind's eye, as we say…"*

The expert flautist, on the other hand, recognizes patterns of notes as a single entity without the need to concentrate on every individual note.

*"Since the sequences the notes represent have also been well practiced, the playing of these sections is now done with little or no conscious effort."*

If this analogy is transposed to design, it turns out that the main difference between novice and expert designers is that the **experts concentrate on the problem-solving task immediately, without separating the problem analysis and solving aspects** (see, for example, Cross 2004).

### *5.1.2.2 Organizational Domain-specific Expertise*

> *"So expertise seems to be a set of learned skills and knowledge probably based on some personal characteristics that facilitate this learning. This then is what distinguishes experts from novices. In this sense expertise is a social construct as well as a cognitive one. It is also the case that expertise exists not just inside individuals but can also be held collectively in teams. We would have no difficulty with the idea that a business or a team has a certain level of expertise that distinguishes it in the marketplace. A great deal of designing is done not by individuals alone but in teams of one kind or another."*

As Lawson and Dorst (2009) acknowledge, instead of looking at the design team as a group of independent individuals with domain-specific knowledge, a successful design team should be viewed as a group of people with shared beliefs and value systems. Throughout the design effort, the design team **socially constructs information from a set of different cognitive frames**. This knowledge construction, however, follows the shared values from within the design team. It is therefore a social process, characterized by **collective domain-specific knowledge**, created through strong cognitive and cultural framing. The designer's professional expertise is, therefore, not entirely subject to an explicit articulation, as it is largely tacit and implicit.

#### *5.1.2.2.1 Neo-institutional Sociology and Institutional Knowledge*

To gain a deeper understanding of the collective expertise phenomenon, I will next briefly review literature on organizational theory that deals with social systems based on the cognitive processes. This body of knowledge is more commonly-known as the *neo-institutional theory*[8]. The neo-institutional branch of sociology incorporates the cultural

[8] Departing from works by the old institutionalists, represented by such scholars as Max Weber, who focused on bureaucracy and solidified the importance of formal institutions in everyday organizational life, a relatively recent stream of research in sociology has broadened the notion of institutions in their formal sense

elements of organizational behavior and, as such, moves from the explicit to the implicit categories of knowledge governing human behavior. Thus, a multidisciplinary field of enquiry focused on socially-constructed values began developing in sociology. One of the pioneering contributions to the neo-institutional sociology was put forth by Berger and Luckmann (2007/1966), in a theoretical study that discusses the relativity of knowledge depending of its social context in the following way:

> *"Sociological interest in questions of "reality" and "knowledge" is thus initially justified by the fact of their social relativity. What is 'real' to a Tibetan monk may not be "real" to an American businessman. The "knowledge" of the criminal differs from the "knowledge" of the criminologist. It follows that specific agglomerations of 'reality' and 'knowledge' pertain to specific social contexts, and that these relationships will have to be included in an adequate sociological analysis of these contexts. The need for "sociology of knowledge" is thus already given with the observable differences between societies in terms of what is taken for granted as 'knowledge' in them. Beyond this, however, a discipline calling itself by this name will have to concern itself with the general ways by which 'realities' are taken as 'known' in human societies. In other words, a sociology of knowledge' will have to deal not only with the empirical variety of 'knowledge' in human societies, but also with the processes by which any body of „knowledge" comes to be socially established as reality."*

In this early contribution to neo-institutional sociology, it is argues that a new field is needed, called sociology of knowledge. Neo-institutional sociology continued its development through contributions from economics, political science as an intertwined body of knowledge. Relatively recently, Richard Scott (2008/1995/1995) took up a laborious effort to categorize thus far known contributions in neo-institutional theory and came up with a new definition for institutions.

> *"Institutions are comprised of regulative, normative, and cultural-cognitive elements that, together with associated activities and resources, provide stability and meaning to social life."*

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of regulations and politics. As opposed to the old institutionalism, neo-institutionalists move beyond the utility maximization paradigm in organization research and acknowledge the value of both formal and informal institutions in organizational behavior.

From this definition, it is evident that not only formal, but also intangible elements of collective culture and individual cognition form the institutional environment of an organization. After a comprehensive literature review and, with this in mind, Scott (2008/1995) crafted an inclusive framework of three pillars of institutions comprising regulative, normative and cultural-cognitive elements.

In this view, Scott (2008/1995) describes the three pillars as follows:

- The regulative pillar: *"In this conception, regulatory processes involve the capacity to establish rules, inspect others' conformity to them and, as necessary, manipulate sanctions - rewards or punishments – in an attempt to influence future behavior. These processes may operate through diffuse, informal mechanisms, involving folkways such as shamming or shunning activities, or they may be highly formalized and assigned to specialized actors, such as the police and the courts. "*

- The normative pillar: "*Emphasis here is placed on normative rules that introduce a prescriptive, evaluative, and obligatory dimension into social life. Normative systems include both values and norms. Values are conceptions of the preferred or the desirable, together with the construction of standards to which existing structures or behaviors can be compared and assessed. Norms specify how things should be done: they define legitimate means to pursue valued ends… Normative systems are typically viewed as imposing constraints on social behavior and so they do. At the same time, they empower and enable social action… Norms can also evoke strong feelings, but these are somewhat different from those that accompany the violation of rules and regulations. Feelings associated with the trespassing of norms include principally a sense of shame or disgrace or, for those who exhibit exemplary behavior, feelings of pride and honor."*

- The cultural-cognitive pillar: *"Symbols- words, signs, and gestures – shape the meaning we attribute to objects and activities. Meanings arise in interaction and are maintained and transformed as they are employed to make sense of the ongoing stream of happenings… To understand or explain any action, the analyst must take* *into account not only the objective conditions, but the actor's subjective interpretation of them. Extensive research by psychologists over the past three decades has shown that cognitive frames enter into the full range of information-processing activities, from determining what information will receive attention, how it will be encoded, retained, retrieved, and organized into memory, to how it will be interpreted, thus affecting evaluations, judgments, predictions and inferences."*

The three pillars are thus an omnibus of three different theoretical streams whereby the main difference between the "old" and the "new" institutionalists is in the cultural-cognitive element that was not taken into account by classical organization theories. The neo-institutional stream of research in sociology was adopted in organizational literature promptly and today a large body of organizational literature is institutional in nature. The main argument for using the institutional lens in an organizational setting is the assumption that organizations are, *de facto*, institutions.

### *5.1.3* ***Expertise Management***

The above subsections introduce the concepts of design expertise and transactions as an economic representation of project-level design management. Talent management is another term that is used for describing the management of design expertise that is needed in knowledge-intensive industries. In an extensive study with software development teams, Faraj and Sproull (2000) identify the need for expertise coordination besides the administrative mechanisms of resource allocation in design:

*"For simple and routine tasks, administrative coordination (the management of tangible and economic resource dependencies) is required to assign tasks, allocate resources, and integrate outputs. However, for complex non-routine intellectual tasks administrative coordination is insufficient. For such tasks, we propose that expertise coordination (the management of knowledge and skill dependencies) becomes more important during teamwork so that the team can recognize where expertise is needed, located, and accessed. Therefore, team performance is not just a function of having the "right" expertise on the team. Rather, expertise must be coordinated among team members."*

This quote, in my opinion, sheds light on most of the issues encountered in project-level design management. It introduces the complexity of managing individuals and groups of experts in conditions of uncertainty. Complementing the importance of expertise coordination, Cappelli (2008) argues for the need to restructure talent management practices currently implemented in organizations. He proposes a way of thinking based on the just-in-time methodology from supply chain management:

> *"Forecasting product demand is comparable to forecasting talent needs; estimating the cheapest and fastest ways to manufacture products is the equivalent of cost-effectively developing talent; outsourcing certain aspects of manufacturing processes is like hiring outside; ensuring timely delivery relates to planning for succession events. The issues and challenges in managing an internal talent pipeline – how employees advance through development jobs and experiences – are remarkably similar to how products move through a supply chain: reducing bottlenecks that block advancement, speeding up processing time, improving forecasts to avoid mismatches."*

Such a system is, indeed, more appropriate for the today's conditions in the market, where mergers and acquisitions between companies occur very often and company strategies are as volatile as the conditions on the market. However, what is missing from the above representation of expertise management is the collective component of expert knowledge, as elaborated in the previous subsection.

### *5.1.4 Is Design Economics a Blind Spot?*

Design work is almost always conducted in the context projects that can be considered the main entity with economic properties. As such, **management at the project-level** is mostly focused at the **economic properties** of the design effort. It is where issues such as income streams and resource allocation come into play. However, design literature is very scarce on economics and, actually, it can be said that **there is virtually no literature on economics of design**. The lack of academic and professional interest in design economics is most likely caused by the very small amount of design costs when compared to production costs.

As elaborated in subsection 3.2.2, the available practical methods of design management address the budget and resource allocation issues. These issues are, unlike in any production process, of limited value in design. As the previous chapters showed, at the project-level of design management, the **hierarchical decomposition methods followed by resource allocation are not sufficient.** Instead, an additional level of analysis is needed to manage design expertise at the project-level of design.

The following subsection unfolds neo-institutional economics as a promising lens to view project-level design management.

*5.1.4.1 Neo-institutional Economics and Transaction Costs*

The field of neo-institutional economics[9] began developing with the seminal work by Ronald Coase (1937) who studied the existence of firms as integrated economic entities as opposed to a number of economic transactions in the open market. He concluded that there are *"costs of negotiating and conducting a separate contract for each exchange transaction which takes place in the market"*.

The theory of transaction costs has been developing ever since, but the most notable scholar who pushed the theory into the economic mainstream is Oliver Williamson (Williamson 1973; Williamson 1981; Williamson 1989; Williamson 2002). The summary of Williamson's contribution is that the main rule of structuring an organization is to minimize the sum of production and transaction costs in its operation. Simultaneously, a transaction cost occurs each time economic exchanges between separate entities take place. This framework depicts the role of transaction costs in organizational systems in the following way (Williamson 1996):

> *"In mechanical systems we look for frictions: do the gears mesh, are the parts lubricated, is there needless slippage or other loss of energy? The economic counterpart of friction is transaction cost: for that subset of transactions where it is important to elicit cooperation, do the parties to the exchange operate*

[9] The neo-institutional school of thought is in organizational studies supported by its economic branch that came to be known as neoinstitutional economics. The main premise of neoinstitutional economics is that the behavior of economic organizations is governed not only by rational economic agents, but also their environments, recognized as institutions.

*harmoniously, or are there frequent misunderstandings and conflicts that lead to delays, breakdowns, and other malfunctions? Transaction cost analysis entails an examination of the comparative costs of planning, adapting, and monitoring task completion under alternative governance structures."*

According to transaction cost economics (TCE), the three contingency factors that define the rationale behind company governance are (Williamson 1996):

- Asset specificity *"has reference to the degree to which an asset can be redeployed to alternative uses and by alternative users without sacrifice of productive value. This has a relation to the notion of sunk cost... Without purporting to be exhaustive, asset specificity distinctions of six kinds have been made: (1) site specificity, as where successive stations are located in a cheek-by-jowl relation to each other so as to economize on inventory and transportation expenses; (2) physical asset specificity, such as specialized dies that are required to produce a component; (3) human asset specificity that arises in a learning-by-doing fashion; (4) dedicated assets, which are discrete investments in general purpose plant that are made at the behest of a particular customer; to which (5) brand name capital and (6) temporal specificity have been added."*

- Frequency of transactions that produces learning effects and enables the formation of specialized divisions within an organization.

- Uncertainty that is a basic condition of information-processing in organizations.

The contingency factors take part in the decision-making processes significantly. Asset specificity and uncertainty threaten organizations in that asset specificity is believed to be the major cause of opportunistic behavior and uncertainty the major cause of bounded rationality. Frequency, by contrast, can have an advantageous effect that results from learning effects when a certain task is repeatedly executed.

The governance of internal or external transactions in a company is characterized by different levels of interaction between the above three contingency parameters. More specifically, organizations will determine between the basic "make or buy" question, based on the contingency parameters. As resulting governance modes, Williamson distinguishes between the market and the hierarchy basic modes of governance, whereby the former is characterized by third-party contracting and the latter by in-house manufacturing of goods and services.

#### *5.1.4.2 Integration of Institutional- and Transaction Cost Theories*

Although the two above fields have been developing independently, they both use employ the neo-institutionalist idea of cultural cognitive and implicit dimension of organizations. While the institutional theory has concerned itself with accomplishing legitimacy as the core factor in organizational design, transaction cost economics has concerned itself with economic efficiency of organizations. Under this light, the separate economic entities that perform exchange within the transaction concept can be assumed to have characteristics of different institutions in the sense of the social sciences. What this means is that transaction costs occur when different institutions mutually engage in economic transactions.

#### *5.1.4.3 Transaction Cost Economics in Construction and Design*

The transaction-based economic view has been so far extensively used in production sectors, and construction alike. The following is a literature review on transaction cost studies in construction and design taken from Zerjav et al. (2012):

> *"Transaction cost economics (TCE) has been used to answer the question of why the construction industry favors subcontracting over bureaucratic hierarchies much more than the manufacturing sector (e.g., Stinchcombe 1959). Eccles (1981a, b) appears to have initiated the discussion of viewing the construction process as a stream of transactions in his seminal work on the quasi-firm in the construction industry. In essence, Eccles argued that project complexity, size, and the market extent result in extensive and recurring subcontracting in construction. Reve and Levitt (1984) continued the discussion by using transaction cost analysis to discuss contracts as a mechanism to govern the client-consultant-contractor relationships in a construction project. Winch (1989), subsequently included the project-firm dichotomy of the industry, whereby firms, not projects, make decisions about resource allocation transactions. Subsequent to these articles, the TCE discussion in construction has been differentiated into two streams of theory: governance of the boundary between the*

*client and the principal contractor (e.g., Eriksson 2008; Puddicombe 2009) and the boundary between the principal contractor and its subcontractors (e.g., Costantino et al. 2001). An example of the subcontracting discussion is a comprehensive study including a panel of 278 construction firms in Spain, in which Díaz et al. (2000) argue that, as asset specificity grows, firms subcontract less; and as process output diversity increases with intangible assets, firms subcontract more. Walker and Kwong Wing (1999), on the other hand, present project management activities as transaction costs in construction projects. They argue that the role of project management is minimizing the sum of production and transaction costs on behalf of the client. Drawing on these contributions, Winch (2001) proposes a TCE-based conceptual framework for governing the construction process across both the participants in the project chain and the resources that each of the participant uses to deliver the work.*

*To the best of the authors' knowledge, there are few studies concerning the governance of interdisciplinary design within the construction industry using the lens of transactions. The reason why TCE been so seldom used for that purpose is, perhaps, because many of the design operations take place within a single organization instead between a number of them, as in the case of construction operations. We currently know of two studies that use TCE in design context: in the first, Pietroforte (1997) argues for the adoption of new types of organizational structures to handle the information-intensive task of design. In the second study, Winch (2001) identifies construction design as a task with both high uncertainty and low frequency and proposes that organizations handle design either internally or through professional associations."*

## 5.2 THEORETICAL FRAMEWORK AND DISCUSSION

### *5.2.1 Introduction*

Following the domain-dependent descriptions of architectural and engineering design from Chapter 3 of this thesis, it is not difficult to transpose the disciplinary theoretical narrative into the realm of expertise management in design in the built environment. This will be the aim of this chapter. More specifically, this chapter will assemble a theoretical framework for project-level design management based on the theoretical discussions in the previous section and the disciplinary differences in narrative that were introduced in Chapter 3. Similar to the general field of design, not much attention has been paid to economic aspects of design in the built environment. The reason for this situation is that the ratio between design and construction costs is around 5% to 95% of the contract value.

### *5.2.2 The Make-or-buy Framework*

On the basis of the body of literature introduced in section 5.1 and a previously-conducted study on design management in multinational organizations (Zerjav et al. 2012), I propose a macro-level economic concept for project-level design management as a stream of knowledge transactions. While the mentioned study elaborated the intra-firm mode of governance in large multinational design organizations, the aim of the theoretical discussion here is to **elaborate the general make-or-buy problem at the project-level of design management**.

In the transaction-based representation, the transaction consists of applying design knowledge to a project-specific situation. The project creates the demand for domain-specific expert knowledge that needs to be filled with expertise residing in the project office or outside it.

**This means that sourcing the project with design expertise occurs in a knowledge market that needs to be managed through discrete transactions.**

The following figure (Figure 12) gives a representation of the structural options for project-level design management as function of asset specificity and task non-separability.

The framework in Fig 12 defines architectural and engineering design as an asset-specific set of transactions between the contracting office and the above-described knowledge market.

The condition of asset specificity is here embodied in the experts' knowledge that is required to produce design in an interdisciplinary context. Following the previously mentioned study, I will call this type of condition **expertise specificity** (Zerjav et al. 2012):

> *"Expertise specificity is a consequence of firm-specific knowledge and skills that its employees have acquired over the course of time and that are not replaceable by means of third-party contracting."*

On the basis of expertise specificity, two general structural areas can be identified in terms of project-level design management. A high level of expertise specificity generally suggests in-house execution of the work packages. A low level of expertise specificity, however, enables the work packages to be contracted on the market. Expertise specificity is described as individual domain-specific expertise in subsection 5.1.2.1.

The notion of **task non-separability** refers to design managers' capability to decompose the entire scope of work in work breakdown structures for subsequent execution and tracking. Generally, in design as cognitive and social activity task non-separability is perceived to be much higher than in physical production processes, however, there are situations where design can be decomposed, as in the case when a number of stand-alone units are designed.

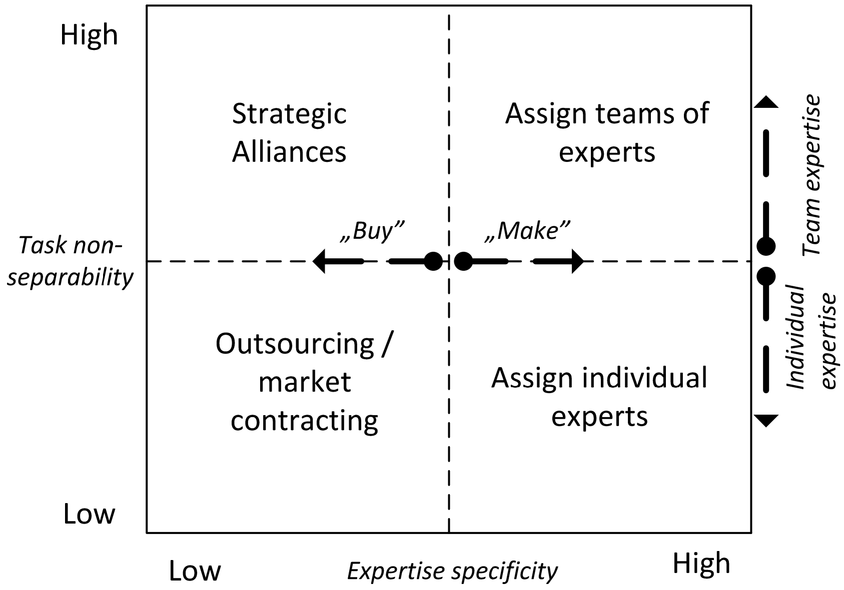


**Figure 12: Framework for transaction-based project-level design management**

With low levels of task non-separability, individual expert contributions are sufficient, as the task assigned to the expert can be clearly isolated. High levels of task non-separability, by contract, will require expert contributions in the form of organizational domain-specific knowlege. Therefore, institutitional knowledge is here employed, as described in subsection 5.1.2.2. In this situation, teams of experts will be employed to deliver the work.

Therefore, the type of domain-specific knowledge needed creates the make-or-buy structural options of design work packages. Based on relative levels of the two identified variables, the framework yields four generic management situations as follows.

1. Low perceived levels of both expertise specificity and task non-separabilility will enable work packages to be clearly defined and **contracted out on the market**. It is a case of one-off contracting where every side goes its own way after the contract has terminated. As a generic representative of the inter-firm approach

2. A relatively high level of task non-separability coupled with a low level of expertise specificity, again, calls for an inter-firm approach in the form of contracting. In contrast with one-off subcontracting, here the work packages are more tightly coupled and closer collaboration is needed within the supply chain

partners. The framework suggests using **strategic alliances**, as they enable long-term relationships that facilitate integration between tasks.

3. A relatively high level of expertise specificity coupled with a relatively low level of task non-separability should dictate utilizing the organization's internal capacity of expertise in the form of assigning **individual experts to the project** as tasks can be isolated.

4. High perceived levels of both experise specificity and task non-separability call for utilizing **internal teams of experts.** Their added value is only achievable when they work collectively as tasks cannot be excessively fragmented in the case of high task non-separability.

### *5.2.3 The Integrated Firm of Architectural and Engineering Design*

On the basis of the above derived project-level management framework, I will also elaborate a firm-level view using the same rationale. The-firm level view will elaborate the development of an integrated firm of **design and engineering as two distinct fields of expertise in the built environment**, but the same reasoning could be applied to a different type of expertise.

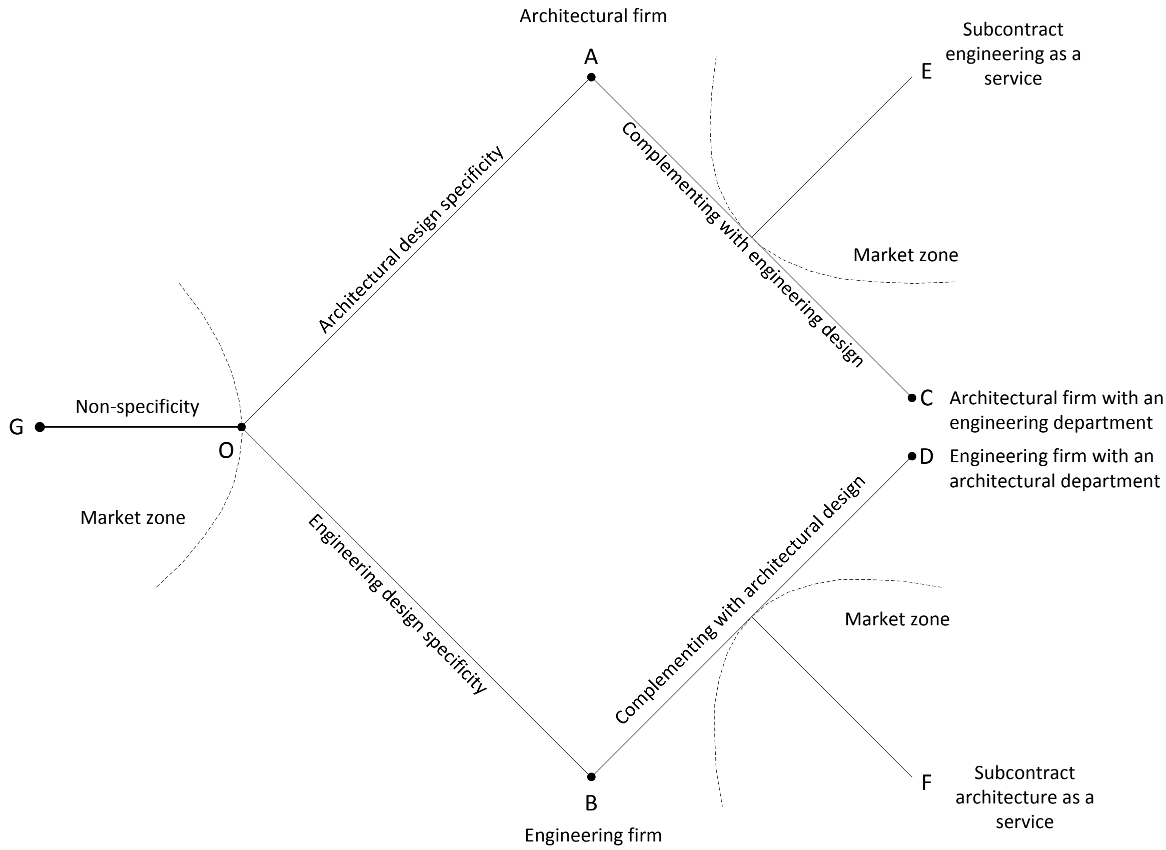


**Figure 13: Cognitive map of developing the integrated the firm of architectural and engineering design**

Figure 13 describes the manager's cognitive process in the development of a design firm in the built environment. The process begins in node O of the framework with an assessment of current expertise available in the existing or potential firm, thus the two main branches of the framework. Following this assessment, managers will logically choose between basing the firm on either architectural (node A) of engineering (node B) range of expertise. However, in most projects the main scope of expertise will require complementing.

1. In the case of the architectural-specific branch, this means that the firm will need to choose between:
   - Buying the complementary engineering expertise from the external knowledge market (node E). This is a scenario that can be implemented when the engineering expertise is non-specific. In this sense, the expertise bought can be considered a commodity, or service.
   - Developing the expertise in internally (node C). This will lead to an architectural firm with an engineering design department. The engineering expertise will thus be developed internally and further asset specificities will be developed on the basis of engineering design expertise.

2. Similarly, in the engineering-specific branch, the firm will need to complement its efforts through:
   - Buying architectural expertise from the external knowledge market (node F). As in the previous case, this is an outsourcing scenario where the architectural expertise is non-specific, in other words, service or commodity.
   - Developing the expertise internally (node D). This will lead to an engineering firm with an architectural department. The architectural expertise will be developed internally leading to further asset specificities in architectural expertise.

3. In the case where the firm does not possess the expertise specific to the transaction, the transaction will take place directly in the open market, and the need for the firm development does not exist.

The cognitive map also shows **the cycle of the integrated firm development and utilization**. The cycle begins with the creation of a firm possessing essentially one kind of expertise. As the firm expands through the internal development of other specificities, the developed expertise can, thus, be implemented in new projects in a way that takes the opposite direction in the cognitive map from Figure 13, which opens up the need for the development of further specificities. This leads to a continuous loop of developing different domains of specific knowledge in the integrated firm. The firm strategy will decide when the inclusion of other domain knowledge specificities should be terminated. This step will conclude the theoretical cycle of the integrated design firm.

### 5.2.4 ***Discussion and Research Findings***

The present section will provide preliminary evidence for the existence of categories in the project-level design management framework. The evidence will also be complemented with anecdotal evidence from the case project that corroborates the four areas of the project-level framework.

*5.2.4.1 Knowledge Market and Expertise Specificity*

The concept of design management as a stream of knowledge transactions between the contracting office and the knowledge market is the basic contribution of the above theoretical frameworks. I support the idea with a quote from an experienced design manager whose main professional engagement has been in large-scale transportation infrastructure design. This person emphasized the importance of expertise next to the traditional resource allocation practices in the "buy" scenario of designing a large scale project:

> *"If you are going to consider a particular office for an assignment on your project, the first thing you want to know is if they have the necessary expertise. If the necessary expertise is not there, it doesn't matter if they are not busy and you are busy, you can't let them help you because it is not going to work. The second question is if there is enough manpower in the other office to perform the work in the time I have available. The third question I look at is if the required individuals are readily available and are they likely to stay committed for the time I need them. My experience has been that good people are normally busy and if someone is sitting there doing nothing, there is quite often a reason for that." - Company D, Senior Engineering Manager.*

Although this quote refers to the demand of expertise, which, therefore, is bought from the knowledge market, the following example refers to the supply side of expertise, where the firm possesses expertise specificity in a domain of design knowledge.

> *"There are definitely so many different aspects of our business, that you can't have expertise in every area in every office. If, for instance, this office is very, very*

*strong in healthcare, but other offices might not have that skill; if they work on a hospital - they can use us." - Company B, Principal.*

*5.2.4.2 Task Non-separability*

The idea of task non-separability is supported with the following quote by the Engineering Director of the Contractor's organization in the case project.

> *"A lesson for the future would be that if you could somehow limit the number of people involved in the parallel design process and if you could have them sitting in the same building and actually working together, that would be very helpful."*

This reference calls explicitly for a collocated mode of design due to the task non-separability characteristics of the case project.

*5.2.4.3 Project-level Design Management in the Case Project*

The design was in the case project subdivided into work packages as the smallest unit of division. However, during the execution of the design, a supply chain was formed that included several design subcontracting organizations. Because of several levels of subcontracting, the initial subdivision on work packages was not kept throughout the execution stage which excessively fragmented the design. As a result, work packages were distributed around more than ten different offices scattered within the country and abroad. This caused a number of integration problems throughout in the execution of design. In terms of the theoretical management framework, the problems with integration resulted from violating the logic of high non-separability.

## 5.3 CONTRIBUTIONS AND RECOMMENDATIONS

### *5.3.1 Theoretical Contributions and Suggestions for Future Work*

This part of the thesis makes a contribution to theory in the camp of **design economics as a developing field**. I believe that the economic representation of design as a **stream of transactions in the market of expert knowledge** is a novel and promising approach for analyzing project- and firm-level issues in design management. This complements theories of transaction-based construction management that acknowledge the extensive use of subcontracting with low levels of vertical integration (Stinchcombe 1959; Eccles 1981b, a; Walker and Weber 1984; Díaz et al. 2000; Eriksson 2008; Puddicombe 2009) with a theoretical **argument for the integrated firm of design,** as previously suggested by Winch (2001).

Moreover, this part further extends the previous author's study on **internal governance in multinational design** organizations (Zerjav et al. 2012) with a more generic framework that encompasses the general make-or-buy problem in design as well as the relation between individual and organizational design expertise.

Finally, this analysis contributes to **general transaction cost theory** (e.g., Williamson 1996) by extending the scope of asset specificity to expertise specificity of design agents. The analysis also contributes to **institutional theory** (e.g, Scott 2008/1995) with an elaboration of **organizational expertise** as institutional knowledge.

Because the interview accounts in this part of the thesis were based on ex-post interpretations by the informants, the continuation of this research should include an in-depth project-level longitudinal study. This study could be designed as participant observation to reveal mechanisms that determine the project-level issues of design management in ongoing decision-making processes on projects. Since theory presented is of descriptive nature, further research should be directed towards the development of normative and predictive theories.

### *5.3.2 Practical Recommendations: The Integrated Firm of Design*

The conclusions at the project-level of analysis advocate the integrated organization structure of the design firm. The results of this study push the long-standing debate on the relation between in-house execution and subcontracting in design towards the integrated firm concept. The main argument for the integrated firm of design is the scope of design interdependence and process-related issues. It becomes clear that systems level integration can be best achieved through an integrated firm of design that is able to encompass the wide range of interdependence at the process level. Fragmentation, by contrast would lead to suboptimal solutions and excessive rework in design. Design managers should, however, not confuse formal integration for process-level integration. More specifically, there is very little benefit from formally integrated organizations whose teams do not collaborate internally at the process-level content of the design. This would lead to a seemingly-integrated organizational structure that is actually more aligned with the international conglomerate concept.

Therefore, the main firm-level recommendation that stems from this study is the difference between construction management and design management. While the former supports fragmented structures with the utilization of a construction management agency that coordinates the interfaces between the subcontracting production systems, the latter requires a much larger organizational structure that is able to exhibit control and impose changes at the process level of a variety of organizational units. In terms of business globalization, this thesis makes an argument that, unlike many other production business sectors, design businesses should internationalize predominantly on the basis of process collaboration and knowledge utilization, rather than on the basis of gaining additional market shares.

## 5.4 SUMMARY

This chapter began by providing an introduction into macro-level theoretical background that is needed to develop a framework for project-level design management. This background includes discussions on the nature of design expertise and its management, as well as an introductory discussion on design economics, as an underrepresented field whose development should be intensified in the future. The chapter then worked out a project-level description of design management by offering an economic representation of design based on the theory of transaction costs. The transaction-based representation assumes design as a stream of discrete exchanges in the expert knowledge market. By further elaborating this idea, this chapter derived a theoretical framework based on the variables of expertise specificity and task non-separability. These variables determine not only the form of the transaction made in the context of the make-or-buy problem, but also the assignment of individual or team expertise on projects. Following the project-level framework, the chapter further elaborates the issue of expertise in the context of asset specificity from the transaction cost theory. The resulting framework gives a theoretical grounding for the development of the integrated firm of architectural and engineering design in the built environment sector. This reasoning is on the basis of the cycle of design expertise development and its utilization during a number of projects executed in an organization. The chapter continued with a discussion section that provides anecdotal validation of the derived framework by using data from interviews as well as the case project studied. Finally, the chapter gives several theoretical contributions and practical recommendations.

# CHAPTER 6:
# CONCLUSION

## 6.1 OVERVIEW OF THE CONTRIBUTIONS

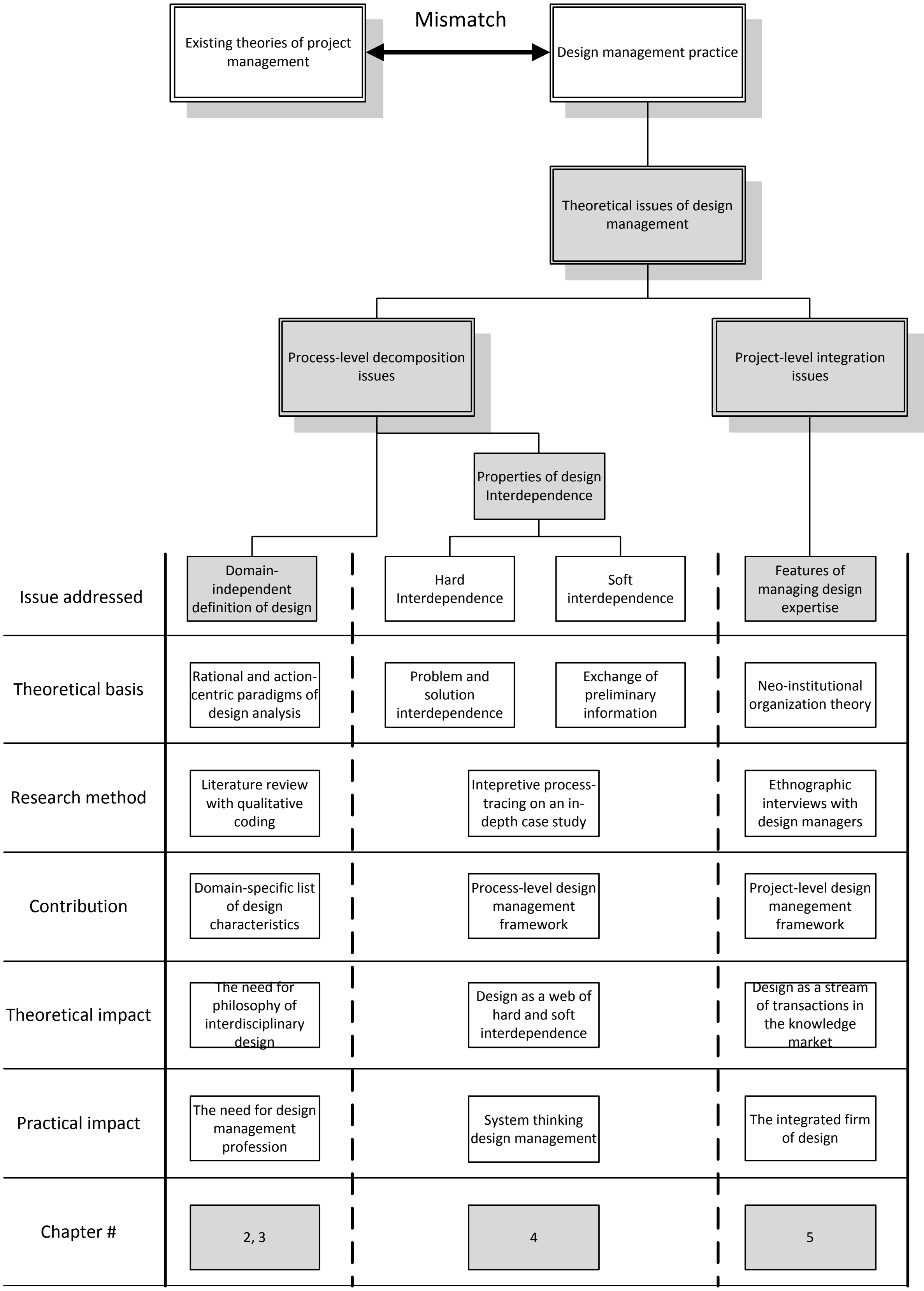


Figure 14: Conceptual overview of the contributions

As Figure 14 shows, at the overall level, this thesis contributes to theory and practice of design management at several levels. The first contribution is the discussion towards establishing the cross-disciplinary definition of design management, and the corresponding profession of multidisciplinary design manager. Based on this definition, the study in this thesis investigates the process- and project-characteristics of design subdivision and integration to come up with an alternative framework for design management that complements existing project management body of knowledge.

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