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Business Innovation Framework for Industrialized Construction

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Abstract

Today's construction is not sustainable. Neither for the construction actor, who is struggling with economic viability, nor for the environment, which is heavily impacted by the construction industry. A major problem of the industry is fragmentation, representing the root cause for difficulties with integral developments, optimizations and innovations. One approach to comprehensively addressing this fragmentation is offered by Industrialized Construction (IC) methods, which introduce platform- and product-based industrialized concepts to the conventionally project-based construction industry.

This thesis focuses on an organizational change analysis for industrialized construction concepts, examining IC on an organizational level from the perspective of today's industry and a conventional construction actor. In this context, the work in a first part synthesizes existing IC literature and frames that in organizational scaffolds. Herein, it maps industrialized construction in its strategic varieties and highlights IC in comparison to conventional construction in terms of construction and business processes and the respective business models, which differ in almost all areas and illustrate the highly disruptive character of IC.

In a second part, the thesis employs a case study to examine innovation barriers that a conventional construction actor has to expect when trying to adapt his business and implement IC as a business innovation, and identifies three innovation barrier patterns which as interrelated implications affect this innovation from its three core stakeholder perspectives: From top-down, the organization's initial economic situation causes a risk-averse behavior, constrains investments in innovation and thus the innovation's progress and impact on this initial situation ('The Vicious Cycle of Construction Innovation'). From the bottom-up, a conforming construction culture of self-interest and limited openness, as well as a lack of communication and collaboration, provoke a lack of active support for innovation and an additional resistance to change from individuals ('The Construction Company's Resistance to Change'). Finally, in its environment, IC encounters an unprepared value chain and infrastructure, and a market in which industrialization and the need for optimized and sustainable building concepts has yet to be established ('The Market Readiness for IC').

Zusammenfassung

Das heutige Baugeschehen ist nicht nachhaltig. Weder für den Akteur der Branche, der mit der Wirtschaftlichkeit seines Geschäfts kämpft, noch für seine Umwelt, die von der Industrie stark belastet wird. Ein Kernproblem des Baugeschäftes ist seine starke Fragmentierung, die ursächlich ist für den schweren Stand integraler Entwicklungen, Optimierungen und Innovationen innerhalb der Branche. Einen Ansatz, diese Fragmentierung zu überwinden, bietet Industrialized Construction (IC), welches plattform- und produktbasierte industrialisierte Konzepte überträgt in die konventionell projektbasierte Bauindustrie.

Diese Arbeit befasst sich mit einer Organizational Change Analyse für industrialisierte Baukonzepte, in der IC auf einer organisatorischen Ebene aus der Perspektive des konventionellen Bauakteurs der heutigen Industrie untersucht wird. In diesem Zusammenhang gliedert die Thesis in einem ersten Teil vorhandenes Wissen zu IC in einen gesamtorganisatorischen Kontext und strukturiert dieses in konzeptionellen Konstrukten für Strategie, Prozesse und Geschäftsmodell. Neben einer Kategorisierung des beobachtbaren Spektrums von IC Strategien erfolgt ein Vergleich von IC zum konventionellen Bauen hinsichtlich der Unterschiede in Bau- und Geschäftsprozessen, sowie in den jeweiligen Geschäftsmodellen, welche sich in nahezu allen Bereichen unterscheiden und den hochgradig disruptiven Charakter einer Industrialisierung des Bauens erklären.

In einem zweiten Teil untersucht die Arbeit anhand einer Fallstudie Innovationhürden, welche einen Akteur der Branche erwarten, der versucht, sein Geschäft zu transformieren und ein innovatives IC Konzept zu implementieren. Hierbei identifiziert sie drei Muster von zusammenhängenden Implikationen, welche aus den drei zentralen Stakeholderperspektiven der Innovation auf diese Einfluss nehmen: Von Top-Down bedingt die wirtschaftliche Ausgangssituation der Baufirma ein risikoaverses Verhalten, hemmt Investitionen in Innovation und somit deren Fortschritt und die Möglichkeit ihrer Einflussnahme auf diese Ausgangssituation ("The Vicious Cycle of Construction Innovation"). In der Organisation selbst provozieren eine diesen Umständen angepasste eigennützige und begrenzt offene Kultur sowie ein Mangel an Kommunikation und Zusammenarbeit eine schwach ausgeprägte aktive Unterstützung für Innovationen und einen zusätzlichen aktiven Widerstand Einzelner gegen Veränderungen ('The Construction Company's Resistance to Change'). In seinem Umfeld schließlich trifft IC auf eine nicht darauf ausgelegte Wertschöpfungskette und Infrastruktur sowie auf einen Markt, in dem sich die Notwendigkeit für Optimierung und Nachhaltigkeit sowie industrialisierte Konzepte erst durchsetzen müssen ('The Market Readiness for IC').

Contents

Acronyms

AEC	Architecture, Engineering and Construction
BEA	U.S. Bureau of Economic Analysis
BIM	Building Information Modeling
BM	Business Model
BMI	Business Model Innovation
CIB	International Council for Research and Innovation in Building and Construction
DfMA	Design for Manufacturing and Assembly
EPA	U.S. Environmental Protection Agency
ESG	Environmental, Social, and Corporate Governance
GC	General Contractor
GP	General Planner
IC	Industrialized Construction
IEA	International Energy Agency
IHB	Industrialized House Building
IPD	Integrated Project Delivery
KSF	Key Success Factors
NHAPS	National Human Activity Pattern Survey
R&D	Research and Development
SCIP	Supply Chain Integration Practice
SME	Small and Medium-sized Enterprise
SROI	Social Return on Investment
TBL	Triple Bottom Line
TVD	Target Value Design

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Chapter 1

Introduction

> *It is not easy to make assumptions about how productive a sector should be in comparison with others, but global labor-productivity growth in construction has averaged only 1 percent a year over the past two decades (and was flat in most advanced economies). Contrasted with growth of 2.8 percent in the world economy and 3.6 percent in manufacturing, this clearly indicates that the construction sector is underperforming. [...] If construction labor productivity were to catch up with the progress made by other sectors over the past 20 years or with the total economy (and we show that it can), we estimate that this could increase the construction industry's value added by $1.6 trillion a year.*

McKinsey Global Institute, 2017

The struggle of the AEC industry with increasing productivity persists since many decades. Regardless of examining data from the U.S. Bureau of Economic Analysis (BEA) back to the 1940s, or looking at historical records in Europe, the picture remains the same: the AEC industry is not even close to keeping up with the average productivity growth of overall economy, not to mention that in pioneering industries such as maufacturing or information technologies. Moreover, as Figure 1.1 shows, studies by the McKinsey Global Institute (Barbosa et al., 2017) demonstrate only very slight increases in productivity over the past 20 years, which at times even declined below the reference value at the beginning of the observation period. In a similar way, the AEC industry performs just as weakly in comparisons of the digitization level. A further study published by McKinsey (Manyika et al., 2015), illustrated in Figure 1.2, places the construction industry at the low end of the scale compared to other industries, with a consistently low level of digitization in all examined areas of assets, processes, and usage. In addition to the advantages of digitization, to develop innovative products or streamline operations, there is also a linear trend between productivity and digitization (Laczkowski et al., 2018), which links the performance of AEC in these areas and indicates that (digital) evolution and innovation are imperative for the construction industry to increase its productivity.

Considering that productivity has a direct impact on performance, the need of AEC actors for optimization, digitalization and innovation becomes apparent, which have a major impact on the 'bottom line' of their businesses - the figure recorded at the very bottom line on a statement of revenue and expenses in the accounting - their net income.

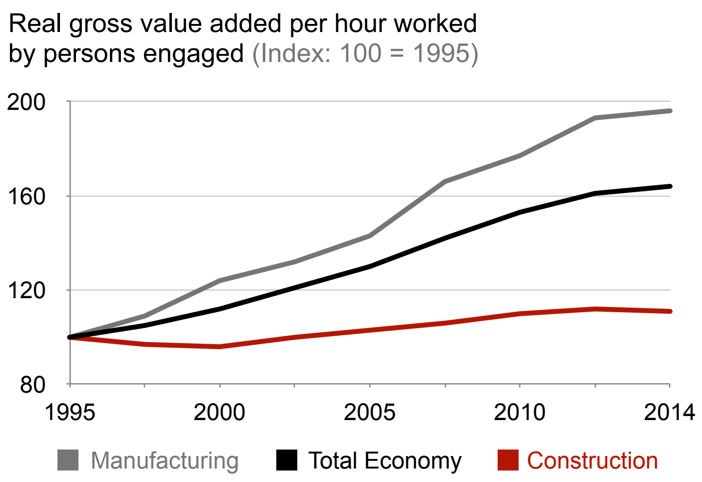


Figure 1.1: Global productivity growth trends (adapted from Barbosa et al., 2017)

Figure 1.2: MGI Digitization Index (adapted from Manyika et al., 2015)

However, if one expands this purely economic view to meet today's needs and includes the dimension of sustainability in the economic efficiency, the impact that such improvements can have becomes all the more significant. In 1994, business author John Elkington expanded the concept of corporate performance as the traditional economic 'bottom line' to include a social and an environmental dimension and coined the notion of the Triple Bottom Line (TBL) (Elkington, 1994), which paved the way for concepts such as SROI, ESG or Circular Economy (Elkington, 2018) and perhaps is more relevant now than ever: People, Planet and Profit.

The impact on people becomes clear when considering not only the work of the AEC industry, the process of construction, but the result of that very work: the built structure. In 2001, a team of researchers commissioned by the U.S. EPA determined in their National Human Activity Pattern Survey (NHAPS) (2001) that people in the U.S. spend an average of 87% of their time indoors (see figure 1.3). Complemented by the time spent in vehicles, which as well is characterized by its infrastructure, the built environment affects more than 90% of people's time. If you manage to improve not only the construction process, but its outcome, the consequences are not restricted to the people working in that industry, but to a large extent on everyone's daily life.

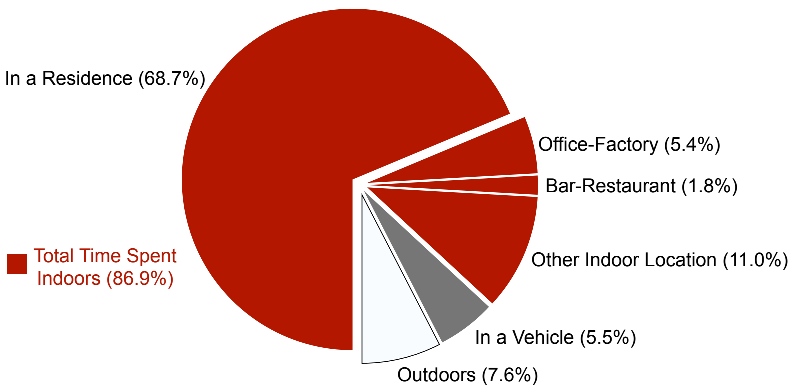


Figure 1.3: Distribution, where people spend their time on average (Klepeis et al., 2001)

The effects on the planet are significant due to the high amount of physical material required for construction. According to the International Energy Agency (IEA) (2019), the building and construction sector accounted for 36% of final energy use and 39% of energy and process-related CO_2 emissions in 2018. In terms of material consumption, this amounts to roughly 40% of the global material resources used each year, and including debris, Construction & Demolition waste account for a similar 40% of annual waste production per volume (Becqué et al., 2015). In light of this, the AEC industry also has a responsibility to contribute to the achievement of climate goals and compliance with the Paris Agreement, and to develop and implement more environmentally friendly building materials, more resource-efficient construction methods, and more closed material cycles.

When considering the TBL, a rapid acceleration of innovation and improvement in AEC is after all not only desirable, but even largely necessary. The fact that a large number of prospective new concepts automatically enable improvement at all the three levels thus actually makes the implementation of innovations in the Architecture, Engineering and Construction industry - as already described by Elkington in the title of his 1994 publication: a Win-Win-Win strategy.

1.1 Fragmentation in the Construction Industry

However, innovations have a hard time in the construction industry (Allmon et al., 2000; Ball, 1999; Orstavik et al., 2015; Winch, 1998). Despite multiple promising approaches, we are seeing only limited progress for years now, which is struggling with low rates of diffusion and is often limited to individual subsectors of the industry.
Past scholarship has identified a major contributing factor for this, which can be found by taking a closer look at the structure of the industry: AEC is characterized by an unprecedented fragmentation in multiple directions (Howard et al., 1989). In construction projects, a high degree of division of labour can be observed horizontally (within one project phase), vertically (between different project phases) (Fergusson, 1993) as well a longitudinally (across multiple projects) (Taylor & Levitt, 2004a). Horizontal fragmentation results from the trade-by-trade tendering of project services, whereas vertically different stakeholders operate in each of the different project phases. On a longitudinal level, the competitive awarding of individual projects leads to an ever-changing composition of project teams. In an environment of regional focus markets, this leads to an industry that is strongly dominated by highly specialized micro and small enterprises. According to the latest U.S. Census, the construction industry comprises over 715,000 establishments, with an average of only 9 employees (U.S. Census Bureau, 2020). Similar in the European Union, almost 90% of employees in the business economy 'Construction of Buildings' are engaged in small and medium-sized enterprises (SMEs), including over 45% in micro enterprises with a number of 0-9 employees (Eurostat, 2020).

This fragmentation already starts in the end market, the real estate market: Both real estate as a capital good and the real estate market show specific characteristics in comparison to other assets and markets (DiPasquale & Wheaton, 1996). A central feature of real estate is its immobility, making the location of the property a decisive factor for its usability and value. Large differences in the land prices and legal requirements of different locations create locally separate sub-markets (Goodman & Thibodeau, 1998; Schnare & Struyk, 1976). The different types of use, each with different requirements, also subdivide the market on a factual level with a large number of highly specialised actors (Adair et al., 1996). The high initial capital expenditure required and the running costs (Nam & Tatum, 1988), together with the heterogeneity and limited transactions of the properties, create an imperfect market with a limited number of investors. Combined with the long construction times of the properties, this results in for the indutry typical economic real estate cycles (Wheaton, 1999), which are characterised by high fluctuations in demand (Maisel, 1963) and consist of phases with supply shortages, low vacancy rates and rising rents, which lead to increased construction activity and, as a result, alternate with a phase of excess supply, falling rents and high vacancy rates. In other words, the real estate market is fragmented in professional, in spatial and cyclical in temporal dimension, driving a large number of players in building and construction, high in specialization and small in size.

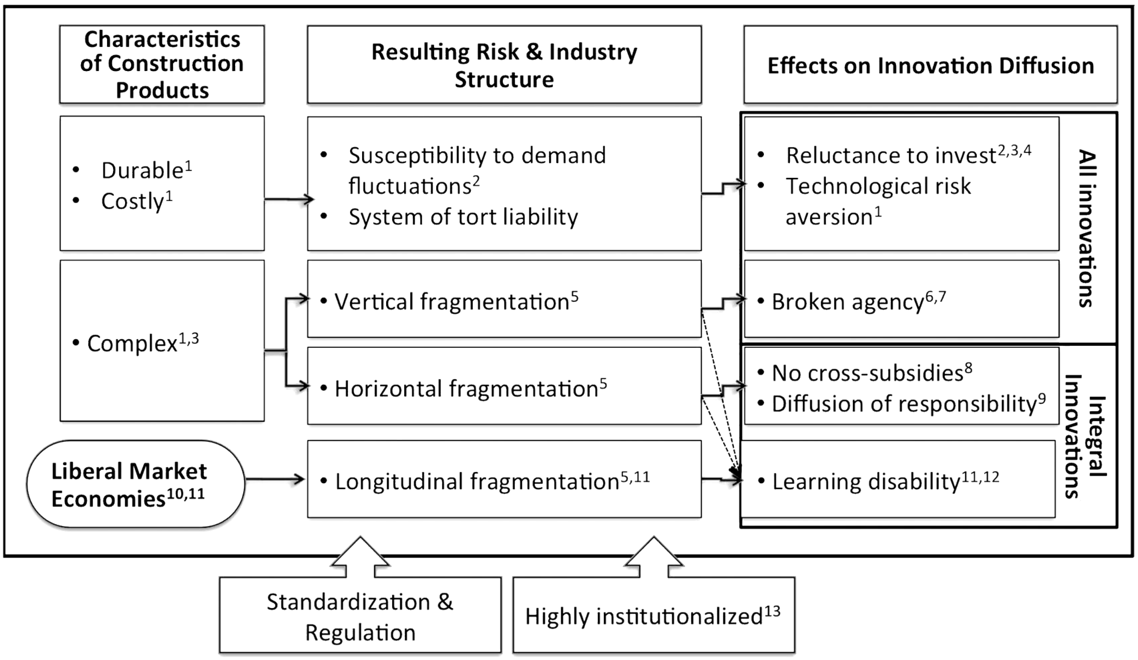


Figure 1.4: Structural Barriers to Innovation in Construction (Sheffer, 2011)
[1](Nam & Tatum, 1988); [2] (Maisel, 1963) [3](Gann, 1996); [4](Reichstein et al., 2005); [5](Fergusson, 1993); [6](Henisz et al., 2012); [7](Murtishaw & Sathaye, 2006); [8](Tatum, 1986); [9](Darley & Latane, 1968); [10](P. A. Hall & Soskice, 2001); [11](Taylor & Levitt, 2004a); [12](Dubois & Gadde, 2002b); [13](Stinchcombe, 1959)

Research by Sheffer (2011) demonstrated that this fragmented structure of the AEC industry generates several barriers for the diffusion of innovations (compare Figure 1.4).

While all innovation is influenced by vertical fragmentation (Fergusson, 1993), liability concerns and demand fluctuations (Maisel, 1963), additional effects from the horizontal and longitudinal fragmentation become visible when innovations are further categorized according to their type.:
Henderson (1990) differentiated innovations according to how they influence existing core concepts and the linkage between different concepts and components (compare Table 1.1). *Architectural (systemic)* and *radical innovations* that imply a change in the concept interfaces, termed by Sheffer as *integral innovations* (Figure 1.4), are additionally impacted by a lack of cross-subsidization within fixed price tendering systems (Tatum, 1986), diffused responsibility structure (Darley & Latane, 1968) and impaired learning opportunities across projects due to the continuous reformation of project teams (Dubois & Gadde, 2002b). *Systemic innovations*, that imply overarching changes in multiple concepts or practices, would require a coordinated and collaborative development of the concepts and their interfaces, whereas the strong fragmentation of the industry represents a massive mismatch to these needed characteristics (Taylor & Levitt, 2004b). Recent scholarship has found that these innovations are three times less likely to be adopted than local innovations performed within the prevailing environment, fitting within the existing divisions of work (Katila et al., 2018). However, the kind of systematic, overarching innovations delivers considerably more global benefit (Sheffer, 2011) and can create increased overall product value or productivity gains (D. M. Hall et al., 2020).

		Core Concept	
		Reinforced	**Overturned**
Linkage between Core Concepts & Components	**Unchanged**	**Incremental Innovation** *Example: Lumber Wall Truss Frame Replacing Conventional Stick-Built Lumber Wall Frame*	**Modular Innovation** *Example: Extruded Metal Truss Frame Replacing Conventional Stick-Built Lumber Wall Frame*
	Changed	**Architectural ("Systemic") Innovation** *Example: Prefabricated Wall Frame with HVAC, Plumbing & Electrical Components Replacing Conventional Stick-Built Lumber Wall Frame*	**Radical Innovation** *Example: Geodesic Dome Frame Replacing Conventional Stick-Built Lumber Wall Frame*

Table 1.1: AEC Innovation Framework (Henderson and Clark, 1990; adapted by Taylor and Levitt, 2004a)

If the likelihood of adoption of such *systemic innovations* is significantly increased by horizontal and vertical integration of project stakeholders during project implementation (Sheffer, 2011), fragmentation of the same should be addressed. However, the integration of tasks and concepts constitutes a challenge for the construction industry. An explanation for this provide Colfer and Baldwin (2016), who identified a "mirroring trap" for the industry: For the coordination of complex interdependent tasks such as construction projects (Galbraith, 1974) , the "mirroring" of technical dependencies and organizational structures provides advantages for companies to conserve scarce resources (Colfer & Baldwin, 2016).: To reduce the complexity of the entire work it is, according to the principle of information hiding, separated by division of labor into modules that can be processed independently of each other (Colfer & Baldwin, 2016). Actors in the industry are hence incentivized to adapt to specialized knowledge and the fragmented task packages

(D. M. Hall et al., 2020), which represents the economic alternative for them within the prevailing structure of the industry (Colfer & Baldwin, 2016). On the other side of the coin, however, the strict mirroring of the existing structure prevents organizations from reshaping it, implementing changes across the boundaries and addressing an evolution of the industry (Colfer & Baldwin, 2016).

1.2 Reorganization in the Construction Industry

For the AEC industry, this leads to a typical organization of construction projects as *Decentralized Modular Clusters* (Sheffer, 2011). These modular clusters are characterized by a (weak) system integrator, typically the general contractor or architect, acting in large part as an orchestrator of many subcontractors in the supply chain. Hall (2018), however, has recently identified a number of emerging concepts that reorganize fragmentation and implement integrated structures of construction projects and organizations, illustrated in Figure 1.5. As a first step to weaken the fragmentation of individual actors, typically driven by the general contractor, the use of Supply Chain Integration Practices (SCIPs), "project-wide (e.g. not individual or intra-firm) practice[s] implemented to organize information, processes, people and/or firms for the purpose of collaboration and integration within the supply chain" (D. M. Hall et al., 2018) like BIM coordination, Target Value Design or Financial Transparency allow the modular cluster structure to deliver projects in a more collaborative manner.

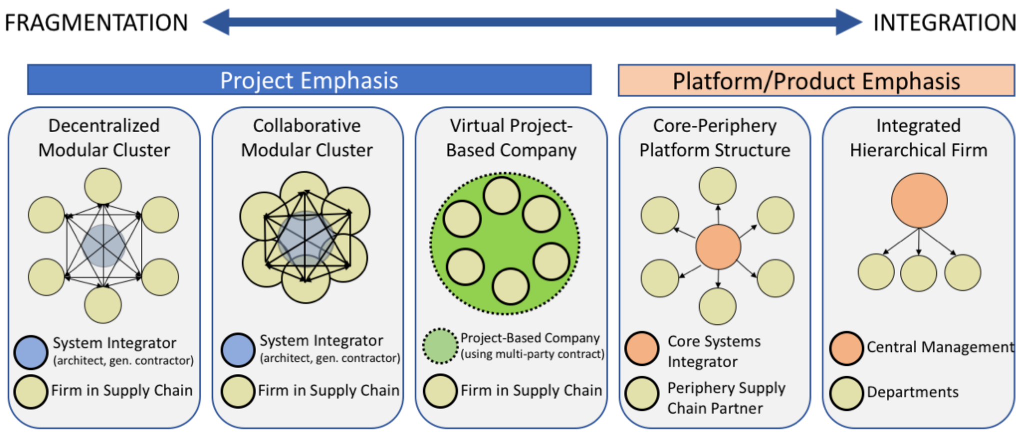


Figure 1.5: Emerging AEC Industry Structure Models (D. M. Hall, 2018)

Institutionalization of this collaboration leads to the formation of 'temporary social organizations' (Thomsen et al., 2009), making use of relational contracting concepts like Integrated Project Delivery (IPD). "The structure of [such a] *virtual project based company* creates vertical integration (including the project sponsor/owner, designers, general contractor, and trade contractors) and horizontal integration (between traditionally separate trade contractors and system designers)" (D. M. Hall, 2018), in a pure organization for individual projects, however, does not yet offer a solution for fragmentation in the longitudinal direction.

Comprehensive integration can thus be seen in a new generation of companies replacing the execution of projects as individual prototypes with a sector-wide development of and project-based recourse to variants of platform-based configurations (D. M. Hall, 2018). These Industrialized Construction (IC) concepts with an emphasis on products typically include a prefabrictation strategy, new business models based on technical platforms, long-term relationships between stakeholders and a Design for Manufacturing and Assembly (DfMA) with high focus on customers (Lessing, 2015). Based on a construct of systematic integration, IC business models enable to restructure the AEC industry towards a more project-independent industry (Vrijhoef & Koskela, 2005a). Depending on the approach and degree of hierarchical integration of the value chain, the spectrum ranges from *Core-Periphery Platform Structures* with capital-light industry 4.0 supply chains and a core digital system integrator, to fully *Hierarchically Integrated Firms* that operate own factories and incorporate design, manufacturing, logistics and assembly in-house (D. M. Hall, 2018).

1.3 Thesis Aim and Format

The aim of this thesis is to investigate the implementation of this new era of IC concepts in more detail. Industrialized Construction, addressing fragmentation comprehensively, according to recent studies offers significant potential to dominate the performance of conventional construction (Bertram et al., 2019) and represents a major pillar of 'The next normal in construction' (Ribeirinho et al., 2020), thus making this sector of research one of the relevant and necessary ones of construction theory at this very time. While the idea of industrialized construction concepts has been around in industry for many decades (Davies, 2005) and detailed studies on technology and industrialized production of buildings have been published for some time (Gann, 1996; Gibb, 1999; Haas et al., 2000), the existing knowledge on IC from a business and organizational perspective beyond technical concepts remains rather limited (Brege et al., 2014; Lessing & Brege, 2015). One topic that has been addressed even less so far is the appropriation of such concepts by prevailing industry actors. However, the appropriately 700,000 existing establishments (U.S. Census Bureau, 2020) in U.S. construction stand against approx. 60,000 annually founded new establishments, out of which only about 25% survive longer than 10 years (U.S. Bureau of Labor Statistics, 2020). Therefore, large-scale implementation of IC concepts will only be achievable when, in addition to new players, a substantial number of existing construction companies adapt their business concepts and transition to disruptive industrialized methods.

For these existing organizations, this transformation means changes in processes, technology and business model and thus belongs to the category of Business Model Innovation (BMI) (Liu et al., 2017). Whereas BMI research in AEC in general lags far behind other industries and in particular for IC is hardly addressed yet (Liu et al., 2017), the most critical part of BMI research is a broader understanding of external and internal implications and mechanisms for these innovations (Schneider & Spieth, 2013). Considering furthermore that speed and success of such organizational changes depend not exclusively on the implementation of hard business concepts, but more on the conversion of soft organizational factors, such as corporate culture or working methods, and that these have to be coordinated to a coherent overall construct (Waterman et al., 1980), the importance of *combined* organizational change anaylses of hard strategic and operational factors together with soft change management issues for these innovations becomes visible. Finally, when bringing together the significance of existing actors for a large-scale implementation of IC, the characteristics of its associated changes for these actors and the state of knowledge of IC from an organizational and business perspective, a research gap becomes apparent, i. e. which changes arise for the AEC actor who wants to industrialize construction and which implications await him in this context, observed in their interaction on a comprehensive organizational level of soft and hard change dimensions. In that context, this thesis aims to contribute to a better understanding of the changes from IC to conventional construction and the path towards that by addressing two research questions:

- What does the concept of industrialized construction mean for the industry player's business and how does it differ from his conventional construction operations?
- Which implications can this actor expect from the stakeholders of his organization when trying to adapt his business and implement such an innovation?

These two questions are brought together in the work as a *Business Innovation Framework for Industrialized Construction*, which has the following objectives from a practical and theoretical point of view:
For the existing players, the transition to industrialized construction to a certain extent represents a disruption of their current business, necessitating to carry out a business innovation. From a practical point of view, the *Business Innovation Framework* documented here can be understood as a conceptual roadmap for the journey of this business innovation, describing possible destinations of the voyage, comparing start and target and analyzing potential barriers along the way.
As from a theoretical point of view such a change from a project-based to an industrialized, product-based industry require not merely the development and implementation of technical concepts, but more so a change in the entire current way of doing business, working and thinking, it is therefore not sufficient to examine only business model and strategy, but rather requires a holistic view of the changeover of the organization in hard and soft dimensions. Thus from a theoretical perspective, the *Business Innovation Framework* can be seen as the approach of an integrated organizational change analysis for industrialized construction, of how the individual business elements are being transformed, what the interactions between them look like, and where potential hindrances may exist in the alignment of these dimensions.
Since a multitude of different actors in the AEC industry from a wide spectrum of business models can approach this industrializing disruption, the framework focuses on a hollistic view of the overall construction process to the extent possible. For comparisons of IC and conventional construction, such as that of process chains and BMs, as well as for the investigation of barriers that may impede IC innovation and disruption, the framework reports from the perspective of the GC, the actor predicted to experience the greatest changes in its business in this future of construction (Ribeirinho et al., 2020).

Following the two research questions, the thesis is divided into two main blocks, which together represent an organizational (change) analysis for IC in interaction of hard and soft dimensions of the organization.

As a vehicle for this organizational analysis the work makes use of the McKinsey 7-S model, which serves as the theoretical basis for the thesis as a whole and is described in Section 1.4. This is followed in Section 1.5 by an explanation of the research methodology used to develop the following two blocks.

Chapter 2 represents a first block that analyzes Industrialized Construction at the level of the 'hard dimensions' - strategy, structure and systems - of the organization and relates that to conventional construction. Based on the existing literature, this chapter first describes the background and concept of Industrialized Construction and highlights its potential benefits. This is followed by a conceptual description of possible IC strategies and their scopes in six strategic dimensions (2.3). Next, it compares conventional construction and IC in terms of the construction process and the core business processes of a construction company (2.4). Chapter 2 ends with linking the hard dimensions in a comparative review of IC and conventional construction business models (2.5). Chapter 2 is not a pure literature review, nor is it primarily aimed at theory building. Rather, the chapter attempts to elaborate and restructure the existing knowledge of IC on an overall organizational business level, framing that within conceptual scaffolds.

Chapter 3 qualitatively examines the implications of transitioning construction business to an industrialized concept, taking into account all hard and soft dimensions of the organization. Based on barriers to innovation and disruption described in the literature, it employs a case study of a construction and construction services company to identify the specific barriers arising for a transition to IC. Drawing from literature, observations and interviews, chapter 3 then describes findings about three interconnected implication patterns that impact the implementation of IC in the ongoing operations of a construction company. These three patterns, termed 'The Vicious Cycle of Construction Innovation' (3.4), 'The Construction Company's Resistance to Change' (3.5) and 'The Market Readiness for IC' (3.6) are interconnected sets of barriers of various organizational dimensions, originating from internal stakeholders from top-down, from bottom-up, and respectively from external stakeholders outside-in on the innovation approach. Chapter 3 offers a synthesis of existing knowledge on innovation, disruption and change management, applied to the specific situation of a construction company trying to implement an innovative, disruptive industrialized construction concept.

Chapter 4 concludes with a discussion of the findings and their placement in the context of construction innovation.
Chapter 5 finally summarizes the contributions of the thesis. It describes contributions to theory and to practice, assesses limitations of the work, and proposes future directions for research.

1.4 Organizational Analysis Research Framework

"The science of management continues to develop as scholars and global business leaders refine their approaches to organizing their enterprises to ensure both profitability and sustainability. There is surely no 'one size fits all' solution that can guarantee success in business. However, among the array of techniques and theories that can help strengthen business, I have always found that the 7-S framework offers a sound approach to combining all of the essential factors that sustain strong organizations: strategy, systems, structure, skills, style, and staff - all united by shared values. The 7-S framework remains one of the enduring elements of diligent, focused business management."

Rajat Gupta, Managing Director McKinsey & Co., 2008, from (Peters, 2011)

The McKinsey 7-S framework is an organizational analysis model by the business consultants Robert H. Waterman Jr. and Tom Peters, developed (Waterman et al., 1980) and applied for the first time (Pascale & Athos, 1981; Peters & Waterman, 1982) in the 1980s. The model, illustrated in figure 1.6, represents organizations in seven dimensions, the eponymous 7 S, all of which are equally important and interconnected. The model is based on the theory that the performance of an organization depends on the fit of all elements, which in the best case are mutually reinforcing. It is often used as a tool for displaying and solving organizational problems and to assess and analyze organizational changes, from changes of leadership or within processes up to new completely processes or new systems (Hanafizadeh & Ravasan, 2011; Ravanfar, 2015).

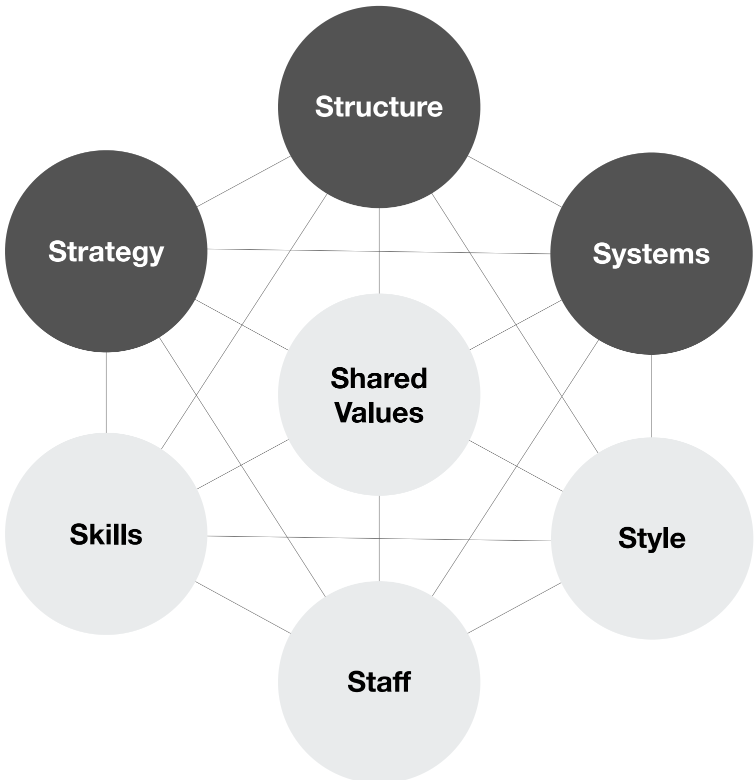


Figure 1.6: The McKinsey 7-S Framework (Peters & Waterman, 1982)

Strategy, *Structure* and *Systems* represent the 'hard' categories of an organization, while *Skills*, *Staff*, *Style* and *Shared Values* can be described as its 'soft' elements. Table 1.6 summarizes a definition of the seven model elements. As Waterman et al. argue, this subdivision is arbitrary to a certain extent, however, it allows to take into account the complexity of organizations and to divide that into manageable parts.

Dimension	**Definition**
Strategy	Actions an organization plans in response to changes in its external environment, intended to achieve competitive advantage
Structure	Mechanisms, by which activities in the organization are coordinated (e.g. authority distribution, task division, department and team structure)
Systems	Formal and informal activities and procedures used to manage the organization (e.g. business processes, control systems, resource allocation systems, reward systems)
Style	Consisting of two elements: • Management style: what managers do (more than what they say), how managers set priorities and spend their time • Organizational style: reflection of a corporation's culture (its dominant values, beliefs and norms), in large parts responsible for its ability to change
Staff	People with their competencies and the human resource management of the company (e.g. recruitment, socialization, training, promotion systems, intrinsic talent management, career development)
Skills	Distinctive competences of an organization (what the company does best): Crucial attributes and dominating capability needs, often changed by strategy shifts (e.g. new market) or structure shifts (e.g. decentralization)
Shared Values	Core values of the organization: guiding principles (vision, mission), typically stated at an abstract level, provide purpose for the employees

Table 1.2: Definition of the dimensions of McKinsey 7-S Framework (according to Waterman et al., 1980; Peters and Waterman, 1982)

Besides the fit of the organization within each element, the "real energy required to redirect an institution comes when all the variables in the model are aligned" (Waterman et al., 1980). An extension of conventional analyses of organizations, solely based on the elements *Structure* and *Strategy* (Miles et al., 1978), enables the explanation of challenges and speed of organizational change, which is geared to all seven S's (Waterman et al., 1980) and provides an approach to explain the success of implementing new business strategies, which historically in the majority of cases remained denied (Kaplan and Norton, 1996; Decker et al., 2012; Cândido and Santos, 2015).

The model is constructed on four ideas which form its foundation and characterize its illustration (Waterman et al., 1980):

- The ability of an organization for change is dependent on a multiplicity of factors, that collectively represent the entire organization and all of which influence its proper mode.
- The failure of business strategies can be traced back to failure in their execution, resulting from insufficient attention to the other six factors.
- All of these factors are interconnected and it is difficult, if not impossible, to make significant changes in any of them without adjusting the others.
- The seven factors are not subject to a hierarchy and a priori it is not obvious which of them will be the critical variable for changes of a particular organization at a particular point in time.

When discussing the model, it must be noted that in its original intention it was designed as a management tool rather than as a comprehensive explanatory theoretical approach, the seven dimensions are generic in their nature and it does not allow to directly derive recommendations for action. Furthermore, the external environment is not explicitly included in the model, although the authors acknowledge that other factors exist and that the McKinsey 7-S framework only depicts the most important dimensions (Peters & Waterman, 1982).
However, regarding its high capability to depict a comprehensive view of organizations, the McKinsey 7-S framework is used in this thesis as conceptual basis to frame the changes and implications of the business innovation towards an industrialized way of construction.

1.5 Research Methodology

The thesis is based on a mixed research methodology approach, which is reflected in the two-part structure of the work and draws from theoretical and empirical data, by applying knowledge from literature and conducting a case study in practice. Figure 1.7 illustrates the research process of this study. The framing of the work is drawn by the McKinsey 7-S Model, on which perspective the thesis builds. The framework, giving a set of general conceptual guidelines (Bryman, 2003), provides a basis to understand the complexity of an object under study (Bunge, 1999) and offers for this work the vehicle for an organizational change analysis for the investigation of IC innovation approaches.

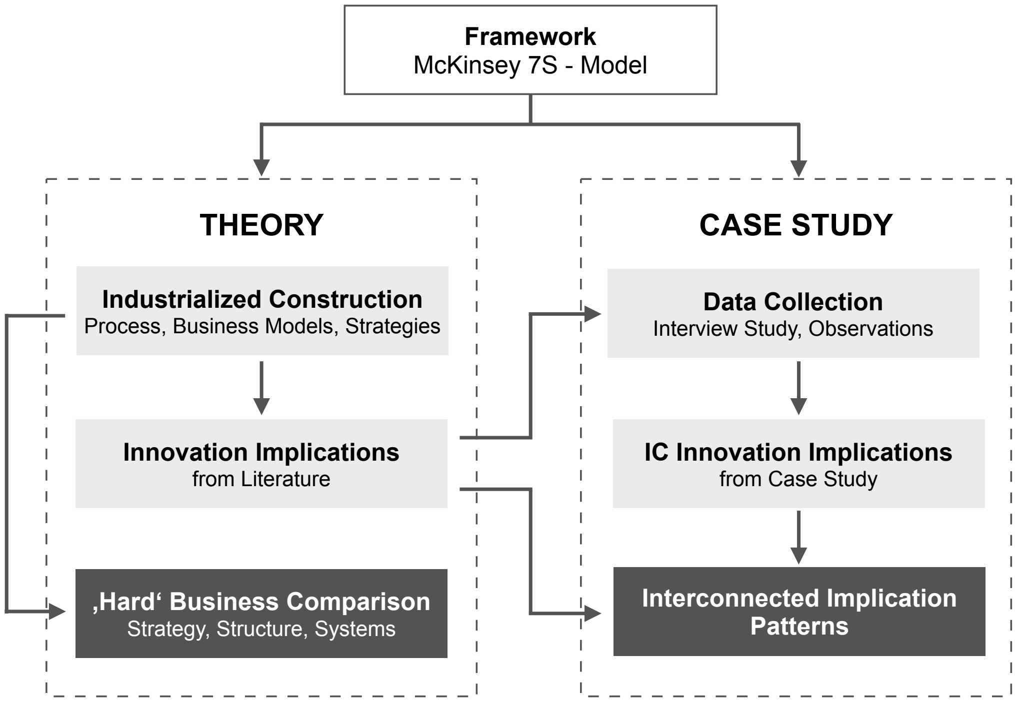


Figure 1.7: Research process

The first part of the thesis, documented in Chapter 2, discusses the IC approach from the perspective of the 'hard' business dimensions based on a review of theory and literature. The methododological approach adopted for this chapter includes a synthesis of IC literature, framing the existing knowledge to establish conceptual constructs for a holistic understanding of IC from an organizational perspective. Emphasis and core focus lies on the explanations of differences of IC to conventional construction in business strategies, processes and business models in a linkage of the three hard organizational dimensions *Strategy, Structure* and *Systems*. Chapter 2 thus does not represent a pure literature review, nor does it follow the methodological approach of new theory generation. Rather, it tries to contribute to the understanding of described concepts and phenomena by restructuring and combining existing knowledge within conceptual scaffolds on an overall organizational level.

Chapter 3 further presents an observation of the implications of IC innovation in an integrated perspective of all organizational elements, including the 'soft' dimensions. According to the theory of the framework, these implications are only of limited meaning when considered separately and receive their explanatory character in a combination of the phenomena. However, such a combined investigation is complex and includes a combination of multiple interrelated aspects. Case study methodology suits this purpose, being the preferred method for studies of complex phenomena with interactive relationships of the variables and situational factors of the environment (Eisenhardt & Graebner, 2007; Merriam, 1988; Yin, 2018). Pure exploratory case study research, however, shows weaknesses in terms of explanatory power and generalizable significance (Easton, 2003; Yin, 2018). A method to address these issues and to bring observated situation-specific effects closer to general theories is a case study approach, that conducts case study research in an iterative process incorporating knowledge from theory and practice (Weick, 1979). Case study methodologies following this principle are particularly suitable when a lot of knowledge about a topic is available, but still needs to be explored in a specific context and setting. Consequently, Chapter 3 follows such an abductive case study approach (Dubois & Gadde, 2002a) using the principle of *Systematic Combining* of theory and empirical world, which is illustrated in Figure 1.8.

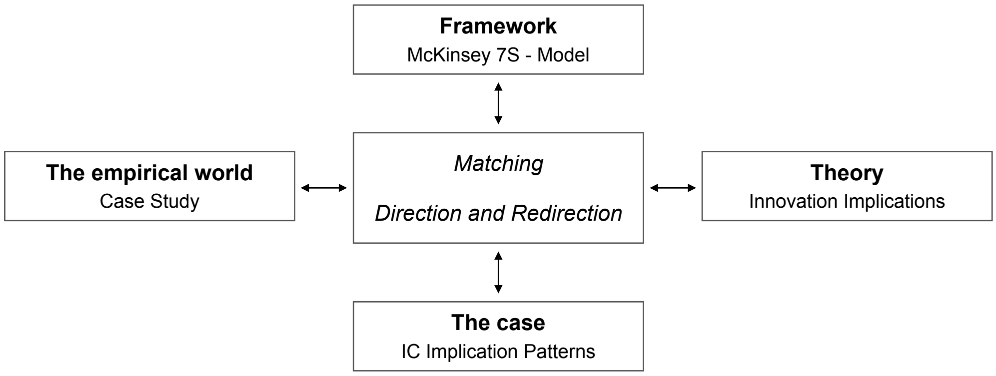


Figure 1.8: Systematic combining case study (according to Dubois & Gadde (2002a))

The principle of Systematic Combining is situated between the *theory explanation* of deductive and the *theory generation* of inductive qualitative research methodology and pursues the goal of *theory development* through systematic linking of theory and reality (Dubois & Gadde, 2002a): In a continuous process of *direction and redirection* of the research process and the information collection methods, a *matching* is achieved, which in a nonlinear combination process with "frequent overlap of data analysis with data collection" (Eisenhardt & Graebner, 2007) explains phenomena combining theory and reality. This process of "abductive matching requires more, and has the potential to yield more, than inductive fit" (Dubois & Gadde, 2002a). Chapter 3, starting from the 7-S model as framework and based on innovation implications described in theory, implements a single case study approach a large Swiss construction and construction services company. The case study, which is further described in Section 3.2, investigates barriers for an IC innovation combined to implication patterns, and includes semi-structured interviews, document studies and observations as the main data sources.

Chapter 2
Industrialized Construction

> *The idea of improving performance in construction by learning from other industries is not new. Manufacturing, the system of production involving the concentration of materials, fixed capital and labour in one or more plants, had long been perceived to demonstrate efficiency over scattered craft production found in traditional housebuilding. Manufacturing provided three main advantages over craft:*
>
> 1. *economies of scale, when the cost per unit drops more quickly than production costs rise as the volume of materials being processed increases;*
> 2. *technical possibilities to develop and deploy capital equipment, and*
> 3. *the opportunity for tighter managerial control.*
>
> Gann, 1996

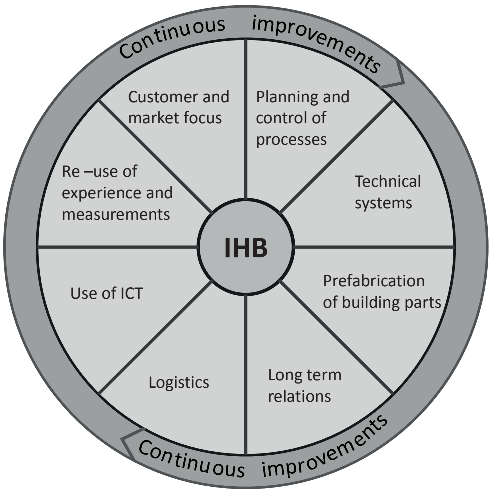
While there is great momentum for the emergence of this new generation of IC approaches in recent years, the concept of industrialized construction per se is nothing novel. As early as the beginning of the 20th century, the first single-family houses were built using, to some degree, industrial methods (Davies, 2005). Le Corbusier, who in 1914 created with the Domino house one of the most influential industrially produced buildings of the time, already argued that "houses must go up all of a piece, made by machine tools in a factory, assembled as Ford assembles cars, on moving conveyor belts" (Russell, 1981). Le Corbusier's ideas had a strong influence on the design and philosophy of the 1960s evolution of 'system buildings', which made use of prefabricated components, new relations with manufacturers and in large parts standardization of processes (Gann, 1996). However, this 'system building' concept, implemented in several of the 1960s mass-housing programs (T. Hall & Vidén, 2005) brought little improvement in overall productivity (Finnimore, 1989) and its functional design and layout and the materials used resulted in products that did not meet the demands of the customers (McCutcheon, 1975). In unstable markets, in which manufacturers were not able to undertake large investments for mass production factories (Gann, 1996), the concept then lost its relevance again in the following years. In the 1980s and 90s, however, the concept of 'modular housing' gained a high level of acceptance among the customers (O'Brien et al., 2000). In the early 2000s ultimately, IC was finally reintroduced and has since gained prominence, targeted by policy in several countries and addressed with increasing attention in the research community (Hosseini et al., 2018).

2.1 The Concept of Industrialized Construction

The term of IC has described a variety of concepts over the years, which followed similar approaches and share a number of common characteristics, but a sharp definition of the expression has remained elusive (Lessing, 2006). The understanding of IC historically originated as a concept of prefabrication and offsite manufacturing, before more comprehensive descriptions gained importance in recent years: In the 1960s, the International Council for Research and Innovation in Building and Construction (CIB) (1965) described the then-widespread prefabrication and use of standardized technology as 'industrialized building'. This term, with mass production as the core concept, shaped the understanding of IC until the 2000s (Goodier & Gibb, 2007), as Hook (2008), for instance, described 'industrialized housing' as "production in a closed factory environment where only assembly is performed at the construction site, with one evident process owner and a clear product goal of repetition in housing design and production." This pure manufacturing scope was then gradually expanded (Barlow & Ozaki, 2003; Gann, 1996), leading also the CIB to attribute in 2010 the following set of aspects to 'Industrialization in Construction':

- Use of mechanical power and tools
- Use of computerised steering systems and tools
- Production in a continuous process
- Continuous improvement of efficiency
- Standardization of products
- Prefabrication
- Rationalisation
- Modularisation
- Mass Production

While all of these definitions focus on production methods and prefabrication as a common point of view, however, IC is a construct that involves beyond production issues aspects of processes, collaboration, market and supply chain (Gann, 1996). Thus, the "most successful Swedish IHB companies show ability to integrate market knowledge, construction technology, production technology, design, building planning, logistics, and product quality into a long-term strategy" (Lessing & Stehn, 2019; Lessing et al., 2015). Lessing was one of the first to provide a comprehensive characterization of what he described as Industrialized House Building (IHB). Figure 2.1 shows a framework he established to describe IHB, including nine characteristic constructs, eight characteristic areas to be integrated and reinforced by a ninth area of continuous improvements, in order to establish IC "with a strategic focus beyond the singular project" (Lessing, 2015).



Planning and control of processes; Processes are thoroughly planned, structured and systematized throughout the organization
Developed technical systems; Technical solutions are developed and structured into systems
Prefabrication; Building parts are manufactured in facilities off-site.
Long-term relations; Participants in the processes are engaged on long-term basis
Logistics; The flow of materials and related information is integrated with design, production and building processes
Use of ICT; ICT-tools and –systems support structuring and managing information throughout all processes and technical systems
Re-use of experience and measurements; Performance measurements give information about process performance and reinforce best practice
Customer and market focus; Thorough knowledge about different customer segments' needs, priorities and expectations
Continuous improvements; Processes and systems are systematically improved

Figure 2.1: Framework with nine characteristic constructs describing IC (Lessing, 2006)

The central component of this concept is the development and operation of building systems and *technical platforms*, on the basis of which standardized buildings are produced (Lessing et al., 2015). These platforms form the backbone for all technical systems, processes, and all building- and system-related information (Johnsson, 2011) and have to be thoroughly designed and continuously improved (Persson et al., 2009) to handle the high complexity of the solutions and to enable the alignment of design, manufacturing, and site work.

2.2 The Promise of Industrialized Construction

The potential advantages of standardized and controlled-production buildings over one-of-a-kind, on-site construction in theory allow to address the improvements in the TBL mentioned in Chapter 1. Prefabrication theoretically offers an increased productivity by potential savings of up to 20% in costs and up to 50% in construction time compared to conventional methods (Bertram et al., 2019) and as a production in controlled factory environments allows an improved control of value chain processes and enhancements in quality control and assurance (Lessing, 2006). Well-organized work environments also increase work safety by reducing both the number of workers needed on-site and the risk of accidents occuring there (Bertram et al., 2019). Moreover, standardized manufacturing methods are a lever for saving material and waste, reducing emissions and energy requirements significantly (L. Jaillon & Poon, 2008).
However, the promised effects still have to be viewed critically and at the project level are in parts still lacking (Blismas et al., 2006). For example, recourse to prefabricated elements under certain circumstances may show cost reductions yet, which however are to a great extent attributable to bulk purchasing (Jang & Lee, 2018) and a large-scale dominance of industrial over conventional building concepts has yet to materialize. Nevertheless, a focus of an implementation of IC on a strategic level rather than just as an operational issue (Lessing, 2015) raises the prospect of the realization of significant benefits (Bertram et al., 2019) and, after slower than expected diffusion in the past decades (Pan et al., 2012), above-average growth of the IC sector in the coming years (Roland Berger, 2018).

2.3 Strategic Dimensions of Industrialized Construction

As numerous as the terminology inscribing the concepts of Industrialized Construction are, so too are the different strategic emphases of organizations following an IC approach that can be observed and have been described by the literature in recent years (e.g. Brege et al., 2014; Bryden Wood Limited Technology, 2017; L. Jaillon and Poon, 2009; Lessing, 2015; Pan et al., 2012). Accordingly, before a comparison of processes and business models of conventional and industrialized construction concepts can be drawn, the first step is to illustrate the range of possible IC concepts, which is located in the dimension of *Strategy*. Figure 2.2 provides a framework to categorize the range of different IC approaches from a business strategy perspective. The framework conceptually describes six dimensions, all of which offer a spectrum of diverse variations. The positioning of different IC concepts within the various dimensions is mutually influencial and is restricted by the respective surrounding conditions of the organization. While theoretically there are few constraints on the combinations, configurations that synergize and show advantages over others certainly prevail. This section, however, focuses on a description of the various parameters, aiming to contribute to the understanding of the variety of IC approaches, without evaluating or contrasting strategies.

	Market	**Business Model**	**Technology**
Concept	**Targeting Segments** *Market Scope and Segments*	**Value Chain Position** *Contribution to the Value Chain*	**Scope of Industrialization** *Contribution to the built structure*
Implementation	**Solution Characteristics** *Customer Segments Prioritization of Price / Value*	**Value Chain Organization** *Organizational arrangement of addressed processes*	**Level of Pre-Specification** *Design entry point for customization*

Starting Point → **Long-Term Strategy**

Figure 2.2: Conceptual strategic dimensions of IC approaches

The IC strategies can be categorized by perspective in scales of the market view, the underlying business model and their technological approach. The initial strategic orientation of the companies is strongly influenced by their starting point, environment and chosen approach (Lessing, 2015). As studies by Lessing and Brege (2018) show, however, the strategic orientation can also shift over time, depending on the actual development and consequent changes in the long-term strategy.

Targeting Segments

Handling construction projects through the operation and use of platforms involves setting certain limits on the organizations' offerings (Lessing & Brege, 2018). Depending on the level of pre-specification, the characteristics of the underlying platform limit the range of different real estate products that can be offered with the respective platform and thus the market segments on which it can operate. A technical platform for modular room systems can efficiently cover only a certain range of physical dimensions, building heights and levels of complexity of room requirements (Bryden Wood Limited Technology, 2017), whereas a platform for wall panels may allow a broader variety of targeted end products. The offer of platform-based buildings therefore represents an offer of solutions within a specific market range and scope, which must be carefully thought through by the organization on a strategic level (Jansson et al., 2014). Accordingly to be successful with this limited offering, the organization must have a clear perception of which market segments its solutions are targeting and which area of the market it wants to cover (Meyer & Lehnerd, 1997). A sufficient number of similar or even identical products to run on the platform furthermore allows to leverage the benefits of standardization (Bryden Wood Limited Technology, 2017). Consequently, in recent years, IC concepts particularly establish in market segments that allow a high level of repeatability, such as hospitality (e.g. Skystone), multi-family housing (e.g. Katerra) or office buildings (e.g. Mace). The spectrum on these market segments ranges from variable concepts with broad market coverage and a focus on processes (e.g. Nautilus, Veidekke) to a targeting of niche markets with highly standardized and specific solutions (e.g. BoKlok, Project Frog) (Lessing & Brege, 2018).

Solution Characteristics

The high specificity of platform-based solutions limits not only the selection of targeted markets, but also the customer segments addressed therein. The design of the products formulates the market strategy of the organization and must be aligned with the demands of the respective target group (Barlow & Ozaki, 2003). In order to design attractive and competitive products, it is necessary to have a clear perception of the client base, an understanding of their needs and the ability to tailor the respective products offered to them (Ulrich & Eppinger, 2011). According to the target group, the degree of customizability and the options of available solutions varies and the emphasis of the products shifts on the price-performance ratio scale from maximally price-attractive (e.g. BoKlok) to flexible, higher-standard solutions (e.g. Implenia), whereby an increasing degree of flexibility is at the expense of standardization and must be carefully weighed against costs, production and process aspects (Schoenwitz et al., 2012). The observed range of solution charactersitics increases with increasing scope of solutions on the finished building, whereas the strategies of vendors with ready-to-use products (e.g. BoKlok, Goldbeck) show more significant differences than those of industrially manufacturing component providers who do not address the end user, but as a supplier serve more homogeneous customer requirements (e.g. Polcom, DBC).

Position in the Value Chain

The organization's position in the value chain illustrates the core principle of its actual business model and determines which services of the value chain are covered by the organization. The value chain position - as a matching share of the value chain which is to be taken over - is limited by the scope of the contribution to the built structure, the target groups and markets to be addressed and the outlines of the offering (Porter, 1985).

Additionally, the targeted position and scale is influenced by the resources available to the organization and the areas of its firm-specific capabilities, giving it competitive advantages in its respective fields of work (Teece et al., 1990). The observable spectrum of different positioning is comparable to that in conventional construction, as it is based on a similar value chain in which, although the processes in the service chain have been restructured, the result of real estate development and project realization, a built structure, remains the same. Thus, the spectrum ranges from manufacturers and suppliers of building components (e.g. Geberit), over turnkey product offerings (e.g. Katerra), to players who take over the entire real estate development process (e.g. BoKlok).

Value Chain Organization

The dimension of the value chain organization describes the classic trade-off of new institutional economics (Williamson, 1991) between market and hierarchy. In contrast to conventional construction, with its typical organization of single-project subcontracting of the bulk of the construction work, the long-term expertise required for IC with a high degree of control of the supply chain features a number of approaches that integrate the entire value chain in-house. While these hierarchically integrated value chain organizations enable an increased product control and higher product complexities, organizations that outsource production, logistics or assembly work in long-term contracts take advantage of open innovation and capital-light industry 4.0 structures (D. M. Hall, 2018). The observable spectrum ranges from purely digital Industry 4.0 system integrators (e.g. Project Frog) over orchestrator approaches (e.g. Skystone) up to fully hierarchically integrated IC companies (e.g. Laing O'Rourke).

Scope of Industrialization

A further dimension of scope defines the contribution of the industrially produced solution to the finished building. Depending on the level of design (Smith, 2010), the scope of the production can range from purely structural elements to fully architectural industrialized elements and from the coverage of a specific trade like bathroom kits, facade elements or wall panels (e.g. Geberit) to modular systems of the entire building (e.g. Goldbeck). Depending on the choice of scope is the selection of the building material used and the setup of the production processes applied (Robertson & Ulrich, 1998), and, in turn, the scope limits the options of positioning in the value chain. The scope of industrialization further describes the proportion of industrial methods used for the product offered. In an environment of manufacturing plants with still limited sophistication and much manual work left, a company's strategy may perhaps in the beginning still include a conventional manufacturing part, and increase the degree of industrialization over time.

Level of Pre-Specification

The level of pre-specification is one of the most influential decisions for the production process and the whole principle behind the industrialized approach. It describes the degree of standardization and componentization and defines the design entry point for customization. The spectrum starts with conventional building methods with little pre-specification, continues with single component manufacturing and volumetric modules and ends at fully modular and standardized building structures (Gibb, 1999). Figure 2.3 illustrates a schematic classification of Hvam et al. (2008) in four levels, which Lessing and Brege (2015) summarized as follows:

- *Engineer to order:* Norms, standards and building codes set the starting point in client controlled project design
- *Modify to Order:* Standardized technical solutions along with strategically defined geometries and solutions for key components. Templates and predefined drawings are used in the project-unique design work
- *Configure to Order:* Predefined parts, components and modules are used for configuring the buildings in a standardized configuration process. Production methods, processes, knowledge and people in the production system set the conditions and limitations
- *Select Product Variant:* Almost complete buildings with some variables are defined in a product development process. Project- specific design is almost eliminated and the majority of all specifications are predefined. Production, assembly, supply chain, sales, etc., are predefined processes tailored for the products

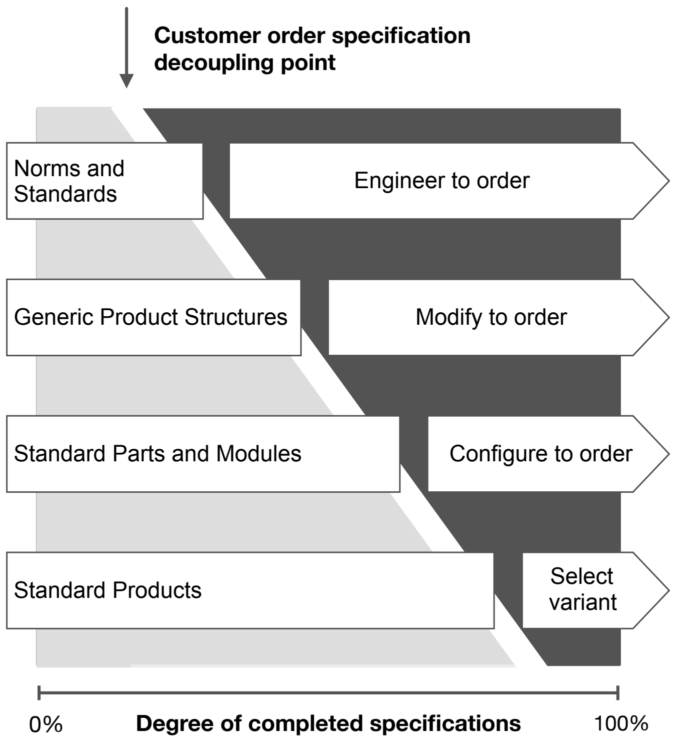


Figure 2.3: Level of Pre-Specification (adapted from Hvam et al., 2008; Hansen, 2003)

An increasing degree of pre-specification increases predictability and process stability (Jansson et al., 2014), but limits flexibility and costumizability of the products. Due to the smaller range of products that can be offered, highly pre-specified products require higher investments in platform development, however, reduce the amount of project-specific work required by increasing the predictability of the products (Lessing & Brege, 2018). Finally, *configure to order* describes a strategy of mass customization, "delivering customised products, but based on thoroughly standardised technical solutions, combined to generate unique end products" (Lessing & Brege, 2018), which has been a particular focus of attention in the recent past.

2.4 The Industrialized Construction Process

After narrowing down the strategic options, the second hard dimension to be investigated is that of *Systems*, representing the process organization of the corporate. With the shift to an Industrialized Construction and planning concept, the orientation of the construction industry is changing from a project-based industry to more project-independent process chains (Vrijhoef & Koskela, 2005a). In the area of building construction with a conventionally pure project organization for individual construction projects (Schmelzer & Sesselmann, 2013), this implies significant changes both in the construction processes at the project level and the primary processes at the business level. Herein, the biggest shift from project to enterprise level takes place in the process of planning and design.

The concept of IC reshapes the basic design principle of buildings, as the *poduct architecture* of industrialized constructed structures differs from that of conventionally built structures. A *product architecture* can be differentiated according to its typology into integral architectures and modular architectures (Ulrich, 1995): Integral architectures are design systems that combine single components individually and create coupled interfaces between the individual components. Modular architectures, in turn, specify a design with standardized mappings and de-coupled interfaces, that allow replacement or modification of individual components and modules for multiple uses.
In conventional construction planning, buildings are planned independently in an integral product architecture, which consists to a large extent of individually constructed elements and to some extent relies on standardized elements (e.g. beams, windows, panels). This integral design results from a planning process in which the architect interprets the client's needs into a functional view, which is together with the engineering disciplines optimized for the individual project-specific requirements (Jensen et al., 2015). However, such project-specific planning leaves little room for flexibility as soon as the share of common parts decreases, as Figure 2.4 left demonstrates. A standardization of this planning thus "is only economic in the select-variant situation, where the number of common parts is large enough to provide economies of scale" (Jensen et al., 2015). Given the heterogeneous requirements of individual construction projects, thus by convention most of the planning is carried out at a project level, without much recourse to standardized design elements.

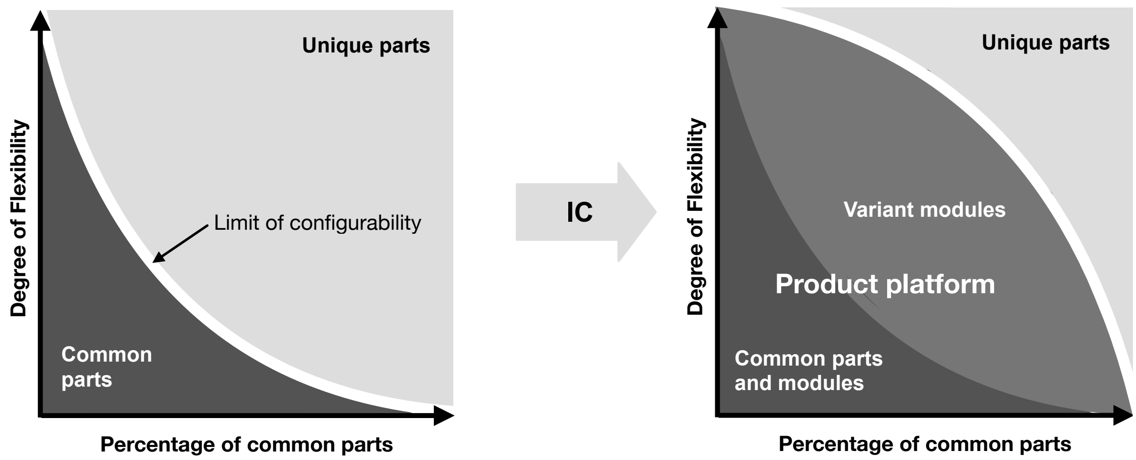


Figure 2.4: Trade-off between flexibility and commonality in construction planning (adapted from Jensen et al., 2015; Robertson and Ulrich, 1998)

This *limit of configurability* can be raised by extending the base of commonality parts by the use of variant modules (Robertson & Ulrich, 1998), which together define a *product platform* for a family of products (Meyer & Lehnerd, 1997) (compare Figure 2.4 on the right). The use of IC concepts for a modular architecture therefore reduces the share of unique parts of the buildings and yields a design structure that can be initially predefined and is intended to meet future requirements and configurations of the modules across projects (Jensen et al., 2015). This principle, supporting the design of a range of heterogeneous structures while using a high number of pre-defined parts, thus allows to lift a large part of the planning from the project level and transfer that to a generalized product platform planning, standardizing the design process as a DfMA concept and reducing the part of the planning for individual projects to a kind of *product configuration*, which is carried out in a project-specific Building Information Model (Borrmann et al., 2018). The entire construction process is hence primarily organized for repetition and then implemented in the separate construction projects (Lessing & Stehn, 2019). This, in consequence, represents only a further standardization additional to the business processes which are already bundled across projects in conventional construction in areas where generalized procedures can be applied, such as warranty, accounting or procurement.

The prospective design shift and standardization implies a significant impact on the core business process of the construction company: For today's typical contractual model (Gottanka, 2017) with planning on the client's side - usually executed by an architect or General Planner (GP) - and a subsequent contracting of the construction services to a General Contractor (GC), this has further consequences on the service distribution of design and planning. Conventionally, as shown in Figure 2.5, the project requirements are interpreted by the client and its vicarious agents in the form of a prototype design, which is calculated by the GC during the tendering process in physical construction work packages and agreed upon in the clarification and contract negotiations (Eber, 2019), with all the work taking place at the project level.

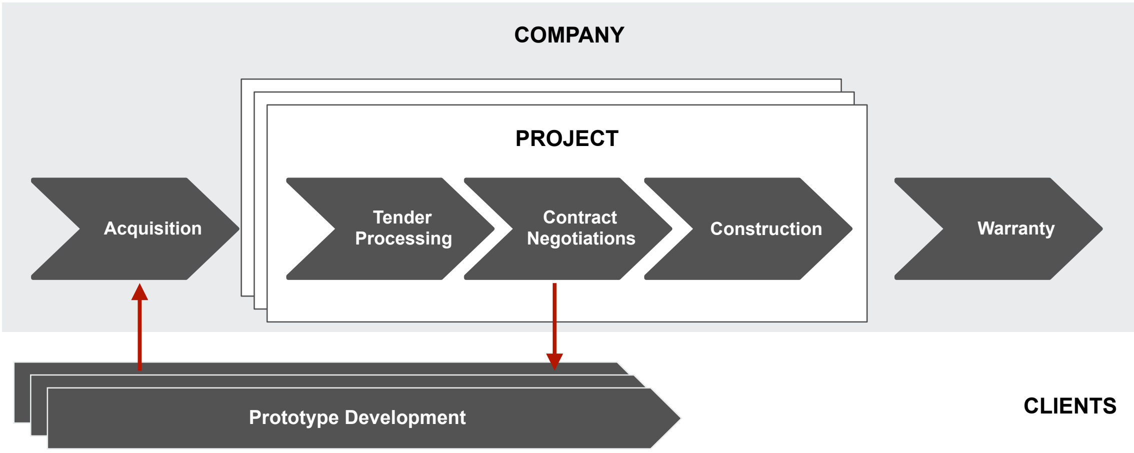


Figure 2.5: Process map of the conventional construction company (adapted from Gottanka, 2017)

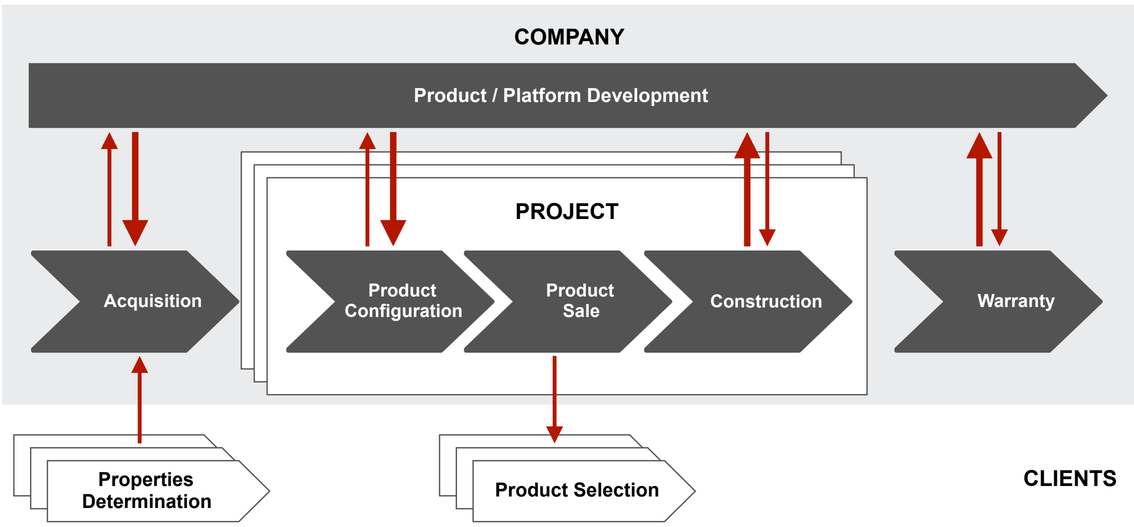


Figure 2.6: Process map of the industrialized construction company

Figure 2.6 shows an industrialized construction business process. Through the standardization of design and construction services, the now compellingly aligned DfMA becomes part of the GC's range of services. The GC develops the basic concepts for an entire product family at a corporate level and uses this base for application to the individual projects. Within the projects, the customer defines his requirements, which the contractor interprets by configuring a product and, during the sale process, finally agrees and selects together with the client. Through a close exchange between enterprise-level platform development and operation and project-level product implementation, the construction company creates feedback loops that facilitate *continuous improvements* (Lessing, 2015) and enable a learning principle that allows the platform to be optimized and continuously updated on the basis of each project, thus providing an improved input for the next project.

On the level of the individual project (compare Figure 2.7), this productization involves the client delegating large parts of the planning work, which, however, also restricts his flexibility. In particular, the specification of his requirements for a product configuration must be completed at a considerably earlier point in time than would conventionally be the case. These necessary early design freezes not only require an earlier basic construction target definition, but moreover are unsuitable for late design changes (L. Jaillon & Poon, 2010) and build on an early certainty of the client over his needs and demands. The design process of the individual project may then lead to longer lead-in times, being additionally affected by the lack of design codes and standards when applying for building permits (Goodier & Gibb, 2005), however reducing the effort of actual planning and design elaboration significantly.

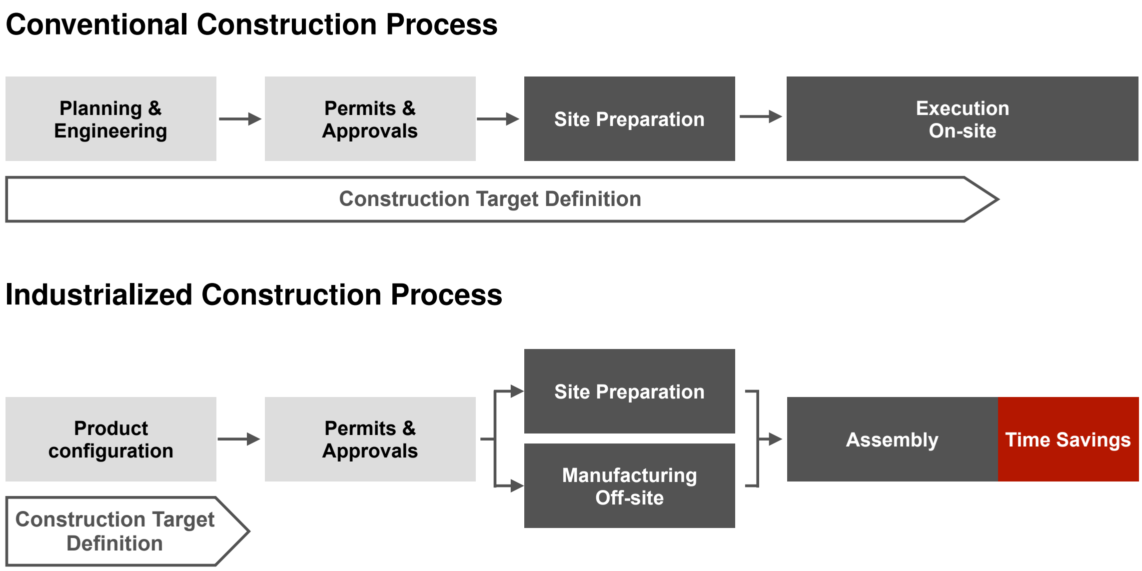


Figure 2.7: Comparison of the project process chains (adapted from Kamali and Hewage, 2016)

One of the most important advantages of IC on the project level is a considerable shortening of the process between ground breaking and occupancy, the changeover of the construction process from on-site execution to prefabrication and manufacturing off-site. This allows not only a project-independent pre-production of elements, but during the project realization simultaneous building construction and site preparation activities (Haas et al., 2000). Together with the construction of geometrically sequenced components such as stacked building floors, that can also be prefabricated in parallel and only need to be assembled sequentially, a task that can be managed efficiently with the help of automated tools (Braun et al., 2020), this results in significant time savings of the execution, which have the potential of up to 50% acceleration of the entire construction process of projects (Bertram et al., 2019).

2.5 The Business Model Shifts of Industrialized Construction Concepts

After considering *Strategy* and *Systems*, *Structure* remains the third hard dimension of the organization to be examined. Unger (2006) has in the context of IC emphasized the importance of organizational structures that are aligned with processes and business strategy, whereas the process changes required to implement the new IC strategies have a significant impact on the underlying business structures of the enterprise. However, following the theory of organizational analysis and the 7-S Framework, a combined consideration of the individual dimensions is even more relevant than a separate investigation of the areas. For that interconnected view, this section integrates the three 'hard' dimensions in drawing a comparison of the *business models* of IC and conventional construction, which show radical differences in alle areas from construction companies that build conventionally what customers uniquely specify, to those that offer buildings with a predefined concept (Pan et al., 2012).

The concept of business models as theory of a business has received attention from many researchers in recent decades (Baden-Fuller & Morgan, 2010; DaSilva & Trkman, 2014; Morris et al., 2005; Osterwalder & Pigneur, 2010), although scholars "do not [readily] agree on what a business model is" (Zott et al., 2011). However, a business model conceptualizes the organization in three aspects (Chesbrough, 2010; Osterwalder, 2004):

- the integration of key components and functions to deliver value to the customer
- the connection of these elements to the organization, through the supply chain and stakeholders
- the value creation of the organization through these interconnections

Brege et al. (2014) further have contributed significantly to the understanding of business models in the context of IC, for which they identified three essential elements: the operational platform, the market position and the offering.
To observe the diferences of IC and conventional construction business models, this chapter follows the business model definition according to Lindgardt et al. (2009), who classify business models into two sides consisting of six pillars, the customer-oriented side of *value proposition* and the *operating model* behind that (compare Figure 2.8). The value proposition is subdivided into the addressed market, the offer tailored to that market and the value creation for the company. The operating model can be further structured into the organizational setup, the associated supply and value chain and the underlying cost model.

Figure 2.8 shows a conceptual comparison of the business models of conventional and industrialized construction, within the scopes of the variety of IC business strategies described in Chapter 2.3.

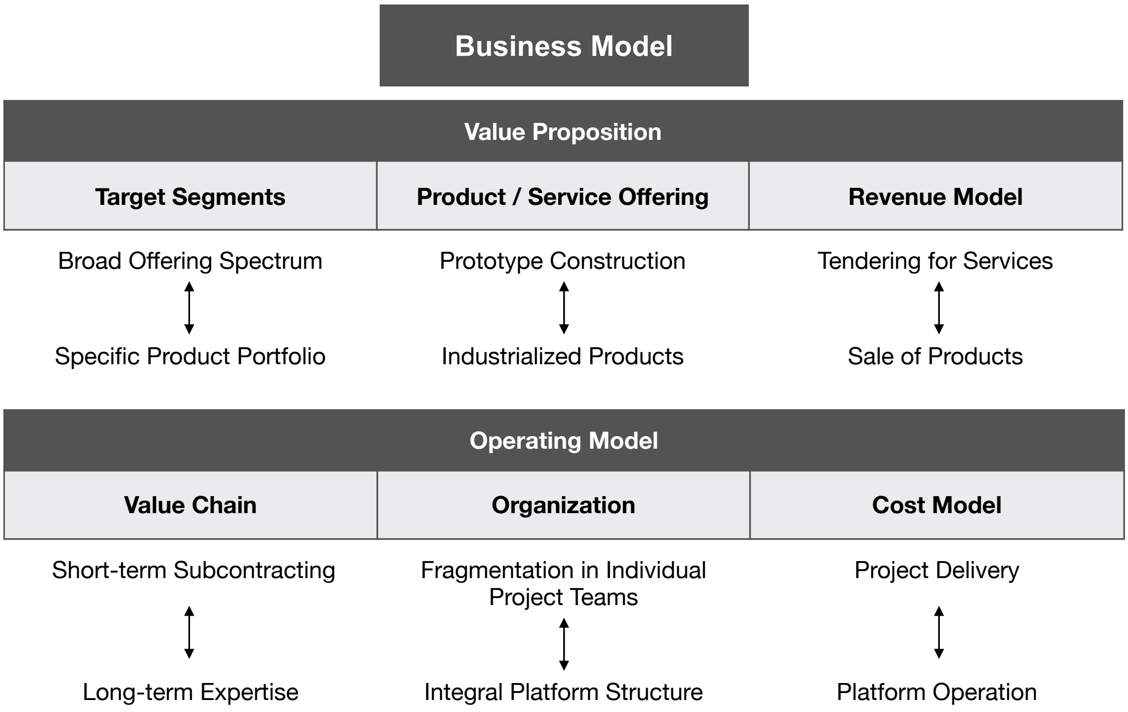


Figure 2.8: Changes of an IC to the conventional construction business model

The differences in the six areas of the business models of industrialized and conventional construction can be conceptualized as follows:

Target Segments

The implementation of individually planned buildings (theoretically) allows an offer of arbitrary designs within the limits of what is technically and economically possible, for a broad market and various customer groups. An IC business model is limited to a specific product portfolio, which is restricted and tailored to specific market widths (Lessing & Brege, 2018), specific market niches (Meyer & Lehnerd, 1997) and specific customer groups (Ulrich & Eppinger, 2011). This limitation makes it imperative to establish a full focus on the client, in order to understand their requirements, meet their needs and create competitive products.

Product / Service Offering

Conventional Construction offers construction as a service, the process of translating planning design into physical construction. Industrialized construction offers construction as a product, which is industrially designed, manufactured, assembled and commercialized. The IC product offering is the combined outcome of the production process, supply chain set-up and business strategy, which are integrated at the level of the entire company (Vernikos et al., 2013) and implement cross-project concepts.

Revenue Model

The value creation of construction projects is based on a sales model. This revenue model is changing from construction as a service process to costruction as an ordered solution. The IC sale shifts the emphasis from acquisition and tendering of services to marketing and sale of products. Additional value added potentials arise in quality assurance and construction time reduction as well as in after-sales activities during warranty and building operation (Bertram et al., 2019).

Value Chain

The value chain structures of the conventional construction company are organized on individual projects and are highly fragmented (Vrijhoef & Koskela, 2005a). A core element of industrialized construction is an integrated organization of the value chain, which includes efficient material and component supply chains for manufacturing and construction (Jonsson & Rudberg, 2014) as well as associated integrated planning processes (Blismas et al., 2006). This integration is most effective at the project-independent level of a certain market segment and on a long-term basis (Johnsson, 2013) and, depending on the strategy of the company, is implemented in-house or on the basis of long-term contracts and partnership cultures (Lessing, 2006) with partners and suppliers.

Organization

The organizational structure of the conventional construction company specializes in handling individual projects and is typically hierarchically fragmented into work divisions and individual project teams (Vrijhoef & Koskela, 2005b). Industrialized construction introduces the cross-project development and operation of a platform system unit. This platform system unites the individual teams and value chain activities, is permanently in close collaboration with project execution, and can be considered a strategic asset (Johnsson, 2011).

Cost Model

The conventional cost model is based on delivering individual projects, with a focus on cost and risk minimization rather than new product development (Nam & Tatum, 1989). An industrialized concept includes development and operation of complex platforms, which involves large financial upfront investments (Lessing & Brege, 2018).These high initial costs for R&D, setup, learning and scaling expose the company to high risks (Vernikos et al., 2013), however under the promise of substantial savings in the long run (Bertram et al., 2019). An in-house integration of manufacturing and operation of own factories furthermore requires even more capital-intensive structures (D. M. Hall, 2018). This cost composition necessitates a shift in cost thinking from an accounting of single project delivery to a profitability calculation of the operation and application of enterprise-wide platform systems.

Chapter 3

Industrialized Construction Innovation Implications

However, the transformation of the construction company that wants to implement industrialized construction does not end with their business concept, but has to equally take place in the way the company is working and thinking every day, in its culture and its organizational behavior (Ivancevich et al., 2014; Robbins & Judge, 2011). These changes take place at the level of the 'soft' dimensions of the organization, in its management and organizational *Style*, in its *Skills* and core competencies, in the way its *Staff* works, and in its *Shared Values*, the visions that unite the organization. A change of these soft corporate dimensions belongs to the subject area of change management (Cameron & Green, 2012) and often represents a major challenge, however is largely responsible for the speed and success of organizational change (Waterman et al., 1980). This chapter therefore investigates organizational changes due to the implementation of IC concepts on an *overall* organizational level, taking into account hard and soft corporate dimensions.

For existing players an IC transformation, with changes in processes, technology and business belongs to the category of Business Model Innovation (BMI) (Liu et al., 2017). From a strategic point of view, BMI is an important business strategy to reinvent existing businesses and sustain commercial values in an new way (Chesbrough, 2010). In practical implementation, BMIs are more comprehensive than product and process innovations and usually more challenging, however, successful business model innovators achieve on average significantly higher premiums (Lindgardt et al., 2009). According to Schneider and Spieth (2013) there are three main areas of BMI research: A research focus on BMI barriers and prerequisites (Chesbrough, 2010; Doz & Kosonen, 2010); a research focus on the BMI process (Demil & Lecocq, 2010; Sosna et al., 2010); and the study of the effects and outcomes of BMI (Sabatier et al., 2012). Schneider and Spieth (2013) concluded a broader understanding of *external drivers* and *internal mechanisms* for BMI as the most critical part of BMI research.
Considering additionally the fact that BMI research in construction generally lags behind other industries with only a few studies on organizational and managerial issues (Liu et al., 2017), the relevance of insights from organizational mechanisms and patterns to explain BMI and disruptive changes in the AEC industry becomes apparent. Consequently, this chapter examines the research question, which barriers and implications an existing actor of the AEC industry may face trying to develop an IC concept in an existing construction organization and to which interrelated mechanisms these implications lead. For this purpose, the chapter follows an abductive case study research methodology by systematically combining findings from theory and practice, starting with an overview of recognized business innovation barriers from the literature.

3.1 Business Innovation Implications from Literature

Literature has dealt extensively with barriers and challenges to innovation at the business level across industries and regions. While the circumstances of innovation vary from case to case and give rise to a number of individual challenges, a range of implications can be identified that are observed independent of the single case and thus be generalized to larger groups of organizations (Madrid-Guijarro et al., 2009). Thus, innovation barriers that are rather content-unspecific and more attributable to the disruptive character of the innovation can be identified across organizations of different regions, company sizes, industries, and environmental conditions, whereby they just remain dependent on the individual case in terms of their extent and severity. *Comprehensive* business innovations, for instance, typically face innovation costs that are difficult to predict precisely (Garcia Martinez & Briz, 2000; Hadjimanolis, 1999) and tend to provoke certain reservations from management (Baldwin & Lin, 2002) and employees (Zwick, 2002). Barriers depending on the size of the company appear among others in high innovation costs (Frenkel, 2003; Galia & Legros, 2004) and more difficult access to financial resources (Hadjimanolis, 1999; Kalantaridis, 1999), which pose problems especially for SME innovators (Madrid-Guijarro et al., 2009). Challenges on the level of culture are in turn influenced by the regional environment (Frenkel, 2003) and the organization itself (Baldwin & Lin, 2002). A set of business innovation barriers with potential relevance for the implementation of IC concepts is presented in Table 3.1 and Table 3.2. These barriers are sorted into external implications (Table 3.1) and internal implications (Table 3.2) and consist of barriers to disruptive business innovation in general as well as specific obstacles of the construction industry, which have an impact on the implementation of innovations in this very sector. It must be noted that the list does not claim for completeness, nor does it assume a consistently high importance of all stated implications for the implementation of IC. There are likely to be further challenges in approaching IC concepts, and not all of the implications mentioned will materialize as hindrances in every attempt. Consequently, list is intended as an *extract of potential relevant implications* documented by business innovation and construction literature, to set a starting point for the following case study.

External Barriers

Innovation Barriers	**Authors**
Lack of Market Knowledge	Zwick (2002), Frenkel (2003), Hewitt-Dundas (2006), Lovell and Smith (2010)
Lack of Market Awareness	Kamar et al. (2009), Lovell and Smith (2010), Park et al. (2011)
Lack of Governmental Regulations	Frenkel (2003), Kamar et al. (2009), Lovell and Smith (2010), Park et al. (2011)
Lack of Technology and Infrastructure	Blismas et al. (2005), Pan et al. (2007), Lovell and Smith (2010), Farmer (2016)

Table 3.1: External Organizational Barriers for Innovation in Construction

External factors that may hinder the strategic innovation orientation result from uncertainties and gaps in the environmental conditions, which for IC in the AEC industry are mainly reflected in incomplete mutual knowledge of stakeholders about the needs of the market and vice versa a limited awareness of this market about the advantages of these concepts (Lovell & Smith, 2010). In addition, the implementation of IC is affected by a deficient legislative and regulatory infrastructure (Kamar et al., 2009) and by a lack of technologically advanced IC actors and suppliers (Farmer, 2016).

Internal Barriers

Dimension	Innovation Barriers	Authors
Strategy	Difficult Innovation Cost Prediction	Hadjimanolis (1999), Garcia Martinez and Briz (2000), Frenkel (2003)
Structure	High Initial Costs of Innovation	Garcia Martinez and Briz (2000), Zwick (2002), Frenkel (2003), Baldwin and Lin (2002), Galia and Legros (2004)
	High Cost Pressure	Pan et al. (2007), Jaillon (2009), Farmer (2016)
	Difficult Access to Financial Resources	Westhead and Storey (1996), Zwick (2002), Frenkel (2003), Galia and Legros (2004)
Systems	Organizational Mechanisms	Pan et al. (2007), Chesbrough (2010)
	Corporation Inflexiblity	Lindgardt et al. (2009), Chesbrough (2010)
Staff	Lack of Qualified Staff	Garcia Martinez and Briz (2000), Zwick (2002), Frenkel (2003), Baldwin and Lin (2002), Galia and Legros (2004)
Style	Manager Resistance to Change	Hadjimanolis (1999), Kalantaridis and Pheby (1999), Garcia Martinez and Briz (2000), Baldwin and Lin (2002)
	Employee Resistance to Change	Zwick (2002), Frenkel (2003), Galia and Legros (2004), Hewitt-Dundas (2006)
	Organizational Culture	Baldwin and Lin (2002), Pan et al. (2007), Chesbrough (2010)
	Risk Aversion	Pan et al. (2007), Chesbrough (2010), Farmer (2016)
Skills	Lack of Collaboration	Pan et al. (2007), Farmer (2016)

Table 3.2: Internal Organizational Barriers for Innovation in Construction

Internal innovation obstacles are mainly found on a cost-related level and on a cultural level. Innovation costs, which are significantly high for IC concepts especially upfront (Lessing & Brege, 2018) and can in general only be predicted to a limited extent (Hadjimanolis, 1999), meet in AEC an economy with consistently low margins and high time and cost pressure (Farmer, 2016), resulting in an increased reluctance to innovate and a difficult access to financial resources (Pan et al., 2007).

Coupled with that high pressure on costs, the industry is dominated by a risk aversive culture (Farmer, 2016), which fosters resistance to change by management and employees (Chesbrough, 2010; Zwick, 2002). In addition to that, the mirrored fragmented structure of the industry (Colfer & Baldwin, 2016) is reflected in fragmented organizational structures and mechanisms, which are not aligned to implement integrative industrialized concepts (Pan et al., 2007).

3.2 Case Study Methodology

These described business innovation and construction industry barriers form the theoretical basis for the concrete investigation of implications for the implementation of IC. The barriers were examined by means of an abductive case study (Dubois & Gadde, 2002a), in which the theoretical knowledge base is systematically combined with direct findings from the economy. The main focus of the case study was the investigation of a large swiss construction company, which operates in the early phase of developing an industrialized construction business model within their organization. Over a period of five months, the study investigated the dynamics of the development team and its internal and external stakeholders, comparing findings from the core research with additional data collected from third party interviews and cross-checking with existing literature. The goal of this repetitive matching process (Dubois & Gadde, 2002a) was to identify implications that arise in the concrete IC development in the interfaces with its environment and the explanatory interplay and linkages between these implications. Since individually identified implications and problem areas have limited explanatory power (Waterman et al., 1980), the study specifically attempted to place the identified phenomena in their interrelationship and thus create an understanding of their root causes and consequences.

The study included several qualitative data collection activities, which are summarized in Table 3.3. Meeting observations were used to gather information on current development issues and the interaction with different stakeholders. In recurring informal discussions with the internal team and with individual stakeholders, findings and phenomena were discussed and different viewpoints and perspectives were explored. Studies of various documents from different points in time were used to compare focus and progress of the development over time as an indicator for issues and implications. Through semi-structured interviews, the study investigated the views of development team and stakeholders on various implications of IC, its development and, in particular, the implementation of such a business model within the existing structures and ongoing business of the organization. The semi-structured interviews averaged between 40 and 80 minutes and were according to the abductive concept used modified over the study period, incorporating new findings and focuses (Dubois & Gadde, 2002a). A basic concept of the questionnaire used for the interviews is documented in Appendix A. This primary data collection within the enrivonment of the case company was backed up and cross-checked with information from eight further semi-structured interviews with third party actors of the AEC industry in Europe and the U.S. as well as business innovation experts from other industries.

Data Collection Method	**#**
Informal Discussions	14
Observative Meetings	4
Document Studies	7
Case Study Stakeholder Interviews	
Real Estate Development	3
Construction	4
Industrialized Construction	5
Supporting divisions (IT, HR, Marketing etc.)	4
External Stakeholders (Clients, Consultants etc.)	4
Third Party Interviews	
Industrialized Construction	3
Construction Management	1
Architects	1
Consultants and Business Strategists	3
Total Number of Interviews	28

Table 3.3: Summary of Source Data

For a comprehensive and objective picture and to increase the limited generalizability of case studies (Easton, 2003; Yin, 2018), the interview study paid special attention to a sample selection that comprised an even balance of all various stakeholder perspectives. On the one hand, the study focused on a balanced ratio of interviews of the development team, the various operative and supporting divisions of the organization, and external stakeholders such as potential customers or investors. On the other hand, when selecting the interviewees, an equally balanced representation of the various hierarchical levels within the organization was taken into account, whereby interviews were conducted with participants ranging from assistants over project engineers to senior and top management. With the consent of participants, interviews were recorded and subsequently transcribed and all interview transcripts and notes were then compiled and coded using the qualitative data analysis software MAXQDA. In this process, key phrases and descriptions of phenomena, either explicit or implicit, were categorized in a multistage procedure: After an initial assignment of implications to the different organizational dimensions, the individual phenomena were continuously combined into different implication patterns and incorporated into a multilevel code hierarchy in their contexts. For the documentation in this thesis, the codes of the interviews, which were held in German or English, were finally translated uniformly into English language.

3.3 IC Business Innovation Implications from Practice

In the case study, participants described 30 different implications and barriers that characterize the construction industry and hinder its development, innovation and industrialization. The implications, which are listed in Table 3.4 along with the frequency of their references, can be sorted according to the origin organizational dimension they belong to.

Dimension	IC Innovation Barriers	References
Environment	Unprepared Value Chain	
	Lack of Experienced Actors	6
	Lack of Trust for Long-term Contracts	5
	Market Readiness	
	Market Awareness of IC	10
	DACH Construction Culture	4
	Incompatible Legal Regulations	5
	Early Design Freezes	3
Strategy	Mismatching Risk-averse Corporate Strategy	9
Structure	Steep Hierarchical Structure	18
	Incentivization for Fragmented Structures	7
	Low Profitability	4
	Short-term Focus on Single Projects	4
Systems	Inflexibility	
	Lack of Digital and Standardized Processes	7
	Lack of Information Flow	3
	Bureaucracy & Inflexible Processes	19
	Earlier Investment Costs	1
Style	Lack of Leadership / Leadership Fragmentation	13
	Construction Culture	
	Conservatism	17
	Self-Interest	14
	Badmouth	11
	Lack of Information and Communication (Pick People up)	27
	Lack of Collaboration	25
	Risk Aversion	6
	Shareholder Interests	5
	Lack of Commitment	15
	0-Mistake-Culture	13
Skills	Lack of Market Knowledge	2
Staff	Role Change of Architects / PMs	6
	Employee Resistance to Change	18
	Fear of Personal Losses	3
Shared Values	Lack of Internal Awareness	14
		294

Table 3.4: Identified Innovation Implications for AEC Innovation and IC Intrapreneurship

Whereas both external barriers from the environment and internal barriers from all organizational areas were mentioned, the various dimensions differ significantly in their refererences and allow initial conclusions to be drawn about about origin and occurrence of challenges. Although technical issues in the implementation of IC were described as a large part of the development effort, they were not counted as major problems affecting the development. Rather, the challenges are found in 'the changes that need to be made from the starting point and the convincement of people for that'. Analyzing the implications according to the frequency with which they were mentioned, taking into account content consistency and emphasis, a picture emerges of which dimensions are described to be most problematic. Table 3.5 shows the most prominent implications sorted by their number of references. The challenges described most extensively are found in the area of management and organizational *Style*, i.e. in the area of the corporate culture. In addition to a culture that shows limited openness to embracing change, stakeholders that are highly focused on their own self-interest, and little cross-team, cross-divisional, or cross-organizational collaboration, there is limited interdisciplinary exchange and communication, and a minimal threshold for uncertain change and experimentation.

Dimension	**IC Innovation Barriers**	**References**
Style	Construction Culture (Conservative, Self-Interest, Badmouth)	42
	Lack of Information and Communication (Pick People up)	27
	Lack of Collaboration	25
Environment	Insufficient Market Readiness	22
Systems	Corporate Bureaucracy	19
Style	Risk Aversion / 0-Mistake-Culture	18
Structure	Steep Hierarchical Structure	18
Staff	Employee Resistance to Change	18
Style	Lack of Commitment (Doing, not Talking)	15
Shared Values	Lack of Internal Awareness	14
Structure	Lack of Leadership / Leadership Fragmentation	13
Environment	Unprepared Value Chain	11
Strategy	Mismatching Risk-averse Strategy	9
Structure	Incentivization for Fragmented Structures	7
Systems	Digital and Standardized Processes	7

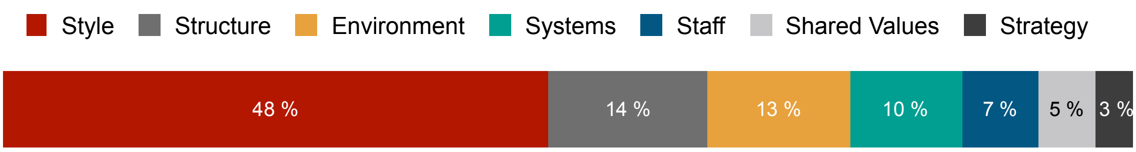


Table 3.5: IC Innovation Barriers sorted by References

Figure 3.1: IC Innovation Barriers summed up by Origin

If the various implications are summed up according to their origin, almost 50% of the challenges can thus be traced back to the prevailing culture (compare Figure 3.1). Furthermore, if one compares this share with only about 3% of challenges that can be traced back to the strategy, this reflects Peter Drucker's well-known statement: *Culture eats strategy for breakfast.* Moreover, the statistic is in line with Waterman et al. (1982), who emphasized the crucial importance of soft business factors for the speed and success of organizational change, which summed up at 60% are opposed by only 27% of barriers at the level of hard organizational issues.
However, looking at the implications separately allows only limited conclusions as to their origins, mechanisms and linkages. Instead, during the study different pattern emerged of implications occurring together and being described by the participants in a coherent manner. Considering that the alignment of all corporate dimensions is of decisive importance for successful transformation (Waterman et al., 1980), an understanding of their interplay accordingly yields theoretical meaning. During the study, participants described combinations of phenomena that can be narrowed down to three main implication patterns. These patterns, illustrated in Figure 3.2, take place in the interaction fields with the diverse stakeholders of the IC approach and occur as mutually reinforcing mechanisms of barriers that negatively influence the strategic approach of innovation, ramp-up of development in its initial phase as well as its scaling during implementation.

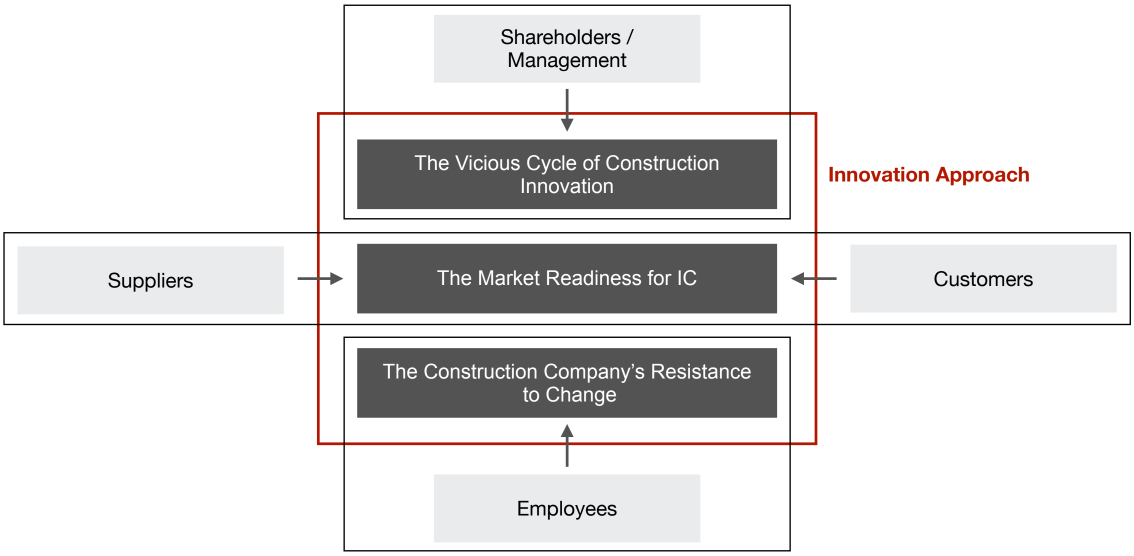


Figure 3.2: Implication patterns by Stakeholder Involvement

From the Top-Down perspective, we observe a Vicious Cycle, which by the economic situation of the construction industry limits the development and impact of optimized innovative concepts on the latter. Bottom-up, the innovation faces a series of issues that together trigger passive and active resistance to change by the organization's internal stakeholders. In addition, IC encounters an environment that is not yet configured for industrialized concepts and where an outstanding market readiness of clients and external stakeholders slows down the implementation of IC and limits its strategic opportunities. Since the individual phenomena discussed are not per se novel findings for the construction industry, the following description of the patterns focuses on the interconnections of the individual issues and their logical relationships described by the participants.

3.4 The Vicious Cycle of Construction Innovation

The first of these patterns describes a combination of implications that have their root cause in the low margins and limited performance of the construction industry. This initial industry situation results for its actors in high working pressure as well as a strong aversion to risky changes. Innovations, which provide for expenditures and only limited measurable results during the R&D phase, thus struggling with principal-agent problems (Eisenhardt, 1989), stand in contrast to this security-driven economy and are constrained in development and scaling by low and unstable investments. Together, that results in a vicious cycle, illustrated in Figure 3.3, which allows only limited impact of the innovation on the core problem, returning the cycle to its origin.

Figure 3.3: The Vicious Cycle of Construction Innovation

Limited Profitability

Construction industry players historically struggle with highly complex projects that yield only limited margins (compare Bertram et al., 2019; Farmer, 2016; Pan et al., 2007). One participant described having 'honestly [] never seen people work so much for so little money as [has has] in the construction industry.' A project manager summed up the problem of the industry, which thrives on handling individual projects, at the project level as follows:

> *'Well, we have a huge resource problem anyway. If things go wrong in the early phase, we burn a lot of money and the project is delayed. That's bad for us, of course, because it means that our earnings also slip back. And [...] we also subsidize many departments. So if something goes wrong internally, we can't forgive it internally, but that has an immediate impact on the whole company.'*

For the implementation of innovative concepts, this has a significant impact on the innovation investments, as 'what we spend in terms of innovation as a percentage of revenue, that is really like, let's say for the industry standard, we are already low, [but] if you benchmark it to other industries, then we're completely out of line', as a participant described. As a consequence, this implies 'a low margin also for error, [...] the average duration of an innovation project cannot be as long as it would be in another industry maybe. So you have to be very creative and fast in testing things out, [...] you have to prove faster that it makes sense.' The financial resources that can be raised for R&D can hence only be allocated low in amount and for limited periods of time.

Shareholder Interests

In the case of large, listed corporations, the use of these limited resources is furthermore heavily dependent on the interests of the shareholders, which have to be satisfied in the first instance. Thus, an IC innovator from a non-listed origin described this very circumstance as 'a huge difference, [as] we have a lot more control over our own destiny', whereas a manager of the listed company implementing IC outlined the trade-off with interests of his shareholders as follows:

> *'It's kind of like that with the knowledge on the one hand that it takes time, right [...]. The corporation has no patience, that's the other side, and that's always this classic conflict of goals that exists there. A family business perhaps has somewhat longer planning horizons than a listed company that moves from quarter to quarter or from half-year to half-year or at least in cycles of two or three years.'*

In addition, these described shorter-term oriented expectations are to be met whenever possible and other issues such as investments in the future have to be taken to the back burner. 'If the group is not doing so well, [...] there is a risk that certain investments will be postponed, which would actually flatten out this nice, steep curve [of the IC implementation].' Furthermore, long-term oriented transformations like the transition to IC stand in contrast to short management cycles of the listed company, which are

> *'rarely longer than two, three, four years and then again some new management has taken over, goes again in [another] direction or gives new conditions otherwise, [whereby] the question is, is there the time now to build [an IC concept] up for two, three, four years [...]. Because actually, [the management] wants to see something sooner than, let's say, in four years, when it's no longer there.'*

In other words, the origin of the problem cycle can be found in limited resources, which cannot be always used in the way that long-term innovations would require. This starting condition has a significant impact on both the progress of innovations and the day-to-day business of the construction company.

High Pressure and Short-term Focus on Single Projects

In the first place, these economic conditions give rise to two problems: the mentioned high financial and performance-related pressure on the one hand, reinforces on the other hand a work approach with an exclusive short-term focus on the individually processed projects. According to a construction innovator, most people 'generally [would] want to innovate, want to do new stuff, they think it's cool, they think it's needed, they also get pushed from the top, but they just don't have the time and resources, they are just so squeezed that I can understand totally that they don't have the time.' In the 'damn complex projects' of the construction industry, the design and construction teams often don't know 'how they could absorb innovation in the context of this complexity that they have to manage', as one project manager noted. Consequently, there appears little room for the development and testing of innovative concepts and, effectively, the only option remaining is to implement innovative solutions once they have been fully matured. As another project manager remarked, there is no time left

> *'to implement half-baked [innovative] ideas. Because the economic pressure on us is, after all, we have an [economic] valuation that we have to meet. Everything that causes us higher construction costs, longer planning times, these are all risks that we have to minimize in the planning phase. So the economic pressure on us is immense and we don't have the money or the time to do groundwork. The risk is too high.'*

The project participants, who are 'already 120 percent busy in their projects', have only marginal time and mental capacities for optimizations and conversions of their concepts, which do not allow them to reflect and change the processes of their daily project business. This situation results in a circumstantial form of risk aversion which is typical for AEC.

Risk Aversion

The foundation of this risk aversion is the basic principle 'that change is valued as riskier [than the existing], this human bias that we sense as well, that you prefer to move where you are and what you know well', as one manager noted. This basic security-oriented attitude is reinforced for the construction actor by his economic situation and reveals in four different phenomena.

0-Mistake-Tolerance

The project performance, which leaves minimal room for mistakes and thus puts maximum pressure on smooth and known processes, manifests in a culture of zero-mistake-tolerance. One project manager described this culture as follows:

> *'From the culture alone, I have the feeling that you have often been punished for making mistakes, and then you are often afraid to make mistakes and experiment, [which alone would be] an extreme culture change. You're always very concerned about safety, including when I'm working internally with the cost estimators, and I understand that, but there's no room for trial and error*

then. Even admitting mistakes, that still has no cultural glory. And that would be extremely important and is probably the change that we need to make first, that cultural change.'

Common pre-judgement and 'dealing with mistakes is certainly totally bad' in the current situation, whereas it actually would be essential that 'everybody has to be comfortable with the idea that at least sometimes something is not going to work', as a construction expert mentioned. In fact, the mindset shift to a willingness to 'do something new even though I've been doing the same thing for the last 20 years' and to the attitude that 'I'm allowed to make mistakes' was unanimously described by several participants as the biggest challenge to innovation within the construction industry. However, for the innovation process, which relies heavily on testing and learning from approaches and will inevitably make mistakes, precisely such an open attitude would be a key factor (Chesbrough, 2010).

Lack of Empowerment

The anxiety about making mistakes and aversion to risks subsequently often results in an inadequate transfer of responsibility and empowerment of subordinates and reveals the first appearance of the vicious circle, as one participant explained:

'So the two go together, right? If I'm scared that I'm going to get in trouble if this job is not done properly, the only way I can be sure that this job is going to get done properly is for me to do it myself. [..] But what happens is that because people take on that responsibility and disempower the rest of the organization, is people no longer do their best, or contribute their best, because they're disempowered. Actually that contributes significantly to the low margin scenario, which increases the consequences, which increases people's unwillingness to delegate, which increases the level of disempowerment, which reduces the margin.'

Little delegation of responsibility therefore has a negative impact on the employees' willingness to work and motivation, who lose the incentive for extraordinary results with the lost of personal responsibility. For the daily business and for the innovator, this has consequences for the performance through a reduced productivity, on the one hand of people and employees and on the other hand of processes, which are delegated downwards only to a limited extent and lead to steeply lived hierarchies.

Risk-averse Corporate Strategy

Risk aversion is also reflected in the corporate strategy, which does not provide commitment for risky and fundamental innovations. While participants during the study differed on how much the organization should and can invest in optimization and innovation, they agreed that there was a 'clear lack of priority' for selected innovation initiatives. When asked about higher investment in innovation, one participant stated:

'The answer is yes, of course. And we would rather cut things elsewhere and invest there. In the end, all this operation excellence stuff is important, of course, but where we will win in the long run is with innovation and with the right people. [...] This high pressure has an influence on the two topics I mentioned earlier, margin and openness of people. You are actually permanently in the short term, you are now trying to optimize here and there so that the framework still holds to some extent and you don't think in the long term because you can't afford that at all.'

Since the strategy is also configured to minimize risks, the organization tends to distribute investments broadly rather than investing substantial amounts of money in specific projects. In contrast, given the general quite limited resources available, fundamental innovations such as the implementation of IC would require strategic and financial focus. 'Instead of distributing a relatively small profit thinly across the whole business, [you end up] not giving anybody sufficient money to really become world class', how one participant summarized the problem. However being 'actually the innovation unit of our division, or one of the most important within our group', promises for the future such as the IC development unit have to continually compete for an approriate strategic position and attention, as participants described. This struggle for prioritization begins in the initial allocation of resources and continues during the implementation of innovation projects, through a fragility in commitment to them.

Lack of Commitment for Changes

This fagile commitment is characterized by a limited level of trust, which at a top level is particularly evident when the innovation is not able to deliver results as planned. Thus, innovators were 'unsure whether we have protected the shoulder' when they talked about their project. As one participant expressed, far-reaching innovations like IC could only be implemented

'with a progressive management and with people who support it, with people who are now prepared to take the risk, that they also stand by it, [also only] with interim milestones. [...] But the important decisions haven't been made yet, now we're in the ramp-up phase, everything's fine, it just gets funny when we realize that we have to write off a million because we made the wrong decision, I don't know. And then questions of principle come up again, like "yes, but that's all bullshit, the million could have been avoided somehow with a conventional construction method."'

What would be needed, especially for disruptive innovations, is 'a leap of faith, and [...] at the moment I still think that's missing', as one innovator summed up. For innovation, the company's risk aversion thus leads to discontinuous commitment and trust, and limited protection and support in the event of unforeseen events. This lack of commitment can become a problem especially when innovations during the development phase achieve only limited measurable results and the extent of their progress is not fully apparent to superiors (Eisenhardt, 1989).

Corporate Inflexibility

The conservative and safety-oriented attitude in combination with the typically large corporate size of the GCs results in an inflexibility of the organization in processes and decision-making, which stands in contrast to an agility that is urgently needed for the successful implementation of innovations. As one project manager described,

> *'agility, for example, [would] actually be anchored as a corporate value, but that's where I have to smile sometimes, because it' s nice to have that anchored, but you have to be. And we still have a lot of room for improvement in that respect.'*

The large enterprise struggles to establish uncomplicated and short process chains and decision-making paths, which in itself would 'actually be an innovation' that would be worth addressing. During the study, a large number of participants described a variety of examples of steep hierarchical structures with decisions that 'always have to be picked up from the top', of a reluctance to make decisions at these upper levels, and of a considerable amount of bureaucracy in processes and procedures. One participant described dealing with this inflexibility as follows:

> *'So then all that happens is you end up trying to work around it. It's a complete waste of everybody's time. [...] The controls [however] are there for a reason, so usually as a result of a bad experience previously, right? So I think the thing is you do your best to work, to follow the process, to follow the guidelines, and you do your best to support those. But at the end, you also expect it to move forward and make money. So at the end, you have to take a risk, and just do some stuff where you can, and hope that you don't get into too much trouble.'*

However, for the development of IC and other innovations, a shortage of agility can quickly become a major threat. Innovation does not have a linear path in R&D, which means that its concepts can change and need to adapt significantly in short periods of time, thus requiring straightforward decision paths, fast processes, and room for experimentation (Chesbrough, 2010). One manager described the situation for the IC development unit of his company as:

> *'The group is rather cumbersome and then there are a lot of processes and units or support functions that like to get involved, that can make the whole thing a bit complicated and slow, yes. I think that's certainly a danger that exists, that a new entity can move a bit more dynamically here, like a start-up or whatever.'*

On the one hand, a certain amount of bureaucracy inevitably accompanies intrapreneurship, as one business developer correctly remarked: 'I think if you really want to do corporate innovation well, you need to accept a certain level of bureaucracy, it is not a start-up environment'. However, he further stated that innovators also 'need to think a bit like a start-up. So if we follow all the internal steps for each process and each administrative step exactly as we should, then we cannot do innovation.'

Too much effort for simple processes can furthermore become a problem for the motivation of the development team, since 'high bureaucracy can be a killer for innovation; people who work on it will at some point lose their motivation if there is too much resistance'. Finally, for the disruptive innovation IC, there is the further hurdle of having cumbersome processes that are not designed to fit an industrialized concept, as according to one manager, the 'structure [of the company] is certainly not aligned for the [industrial] thinking and business model, which would be a whole new world actually.'

Unstable Investments and Impaired Development

The consequence is that resource scarcity, risk-averse behavior and steep hierarchical structures ultimately lead to investments for the implementation of innovations that are low in amount on the one hand and without consistent reliability on the other. Thus, development teams regularly struggled with the 'level of funding, and the funding commitment. The budget [for innovation] is a dynamic beast', as one innovator recalled. Financial coverage of development concepts requires 'constant discussions' and often it is not possible to make investments for long-term improvements, as a project manager commented: 'Projects with investments of several millions and return not until a few years probably will not work anymore [in construction]. However, for disruptive innovations, which are large in scope and require a certain start-up time, a full commitment would be needed for successful development especially in the initial phase, as one manager explained:

> *'When it's good, it's good, then it flies on its own. But it's not quite so simple that it flies so quickly. To make it really significant, we have to prove it, and that's a bet on the future. On a small scale maybe, it is not a Tesla bet. [...] But we need to be fast and full throttle and have the best people, that we somehow manage to prove that.'*

In the specific case of IC, moreover, there are a range of investments that need to be made on a large scale during the ramp-up phase to ensure later scaling and profitability, like investments in technology learning or feedback loops. One IC developer for instance described his experiences with comprehensive initial investments in retrospect as

> *'there was initial experimentation [within the company] with pre-fabrication prior to [the IC business] where they would do offside fabrication on a smaller scale, on a more regional scale, even at project level. They realized that that just wasn't working, they weren't getting the efficiencies and the cost effectiveness that they were looking for.'*

Finally, with limited progress and scalability, the vicious cycle completes with an equally limited impact that the innovation can have on the organization's performance.
Within this big cycle, a constant interplay between barriers and development progress furthermore provides shortcuts and discards that have the potential to reinforce the main loop. Limited progress increases risk aversion, limited scalability reduces funding commitment, bureaucratic processes do not allow for fast proof of concepts.
However, in theory, it would be possible to break this vicious cycle at any place and point in time.

3.5 The Construction Company's Resistance to Change

Employee resistance against innovations is an important barrier against necessary innovations and a source of irritation in industrial relations. It therefore can be of crucial importance for the competitiveness of those firms that plan to innovate to know when they have to expect employee resistance and how to handle it.

Zwick (2002)

A second barrier pattern can be found in the bottom-up stakeholder perspective regarding the relationships between the innovation initiative and the organization's other internal stakeholders. As Schumpeter already 1942 argued, every economic development represents a kind of creative destruction of the prevailing processes. This is especially true for business innovations such as the industrialization of construction, which can be classified as disruptive on a large scale. Thus, such changes typically induce resistance from other employees of the organization (Zwick, 2002), which is expressed in the pattern of *the Construction Company's Resistance to Change* (compare Figure 3.4) in a lack of active support and collaboration for innovations and an additional passive resistance of people to changes. Lack of active support for innovation results from a company culture of low collaboration, self-interest and conservatism, coupled with a limited understanding and belief in the impact and implementability of the innovation. Added to that comes a further resistance of individuals to change, which on the one hand derives from their high working pressure and associated risk aversion, and on the other is caused by unsufficient communication and engagement with the respective individuals, resulting them to perceive changes as potentially harmful for themselves.

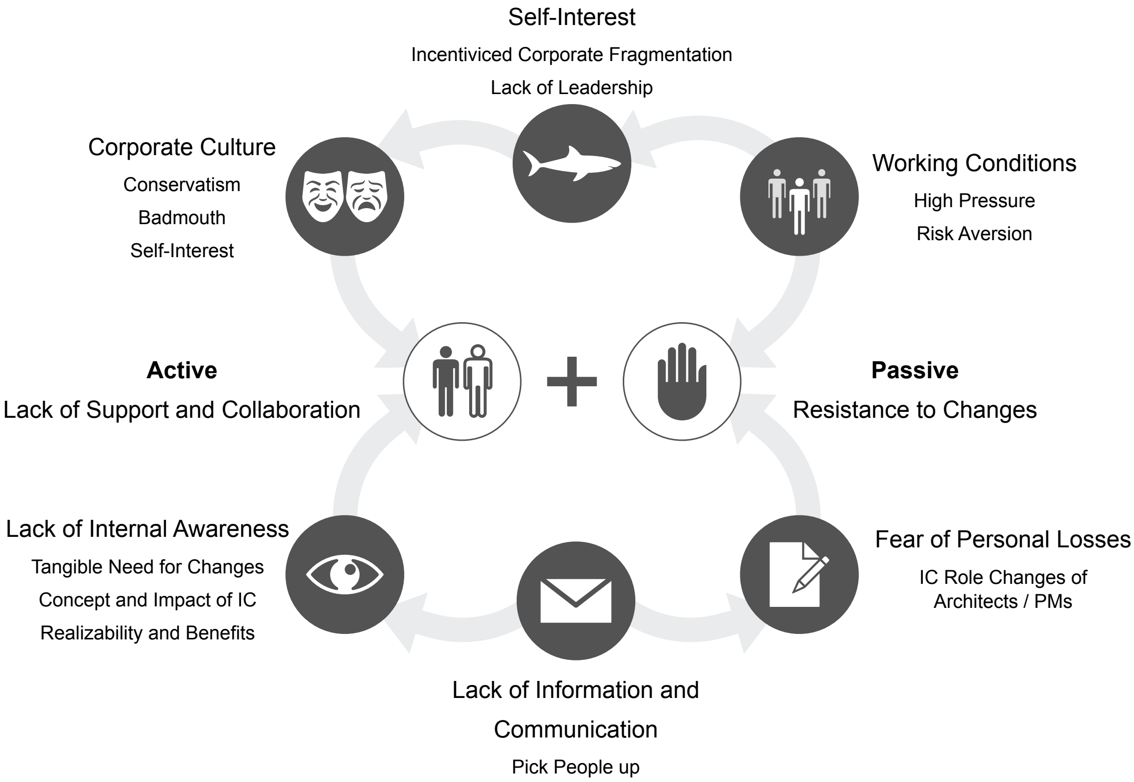


Figure 3.4: The Construction Company's Resistance to Change

Working Conditions

The aforementioned working conditions on construction projects and a consequent risk aversion have a similar impact on the willingness of employees to cooperate and their openness to change. Frequently, the economic constraints in construction leave people marginal space to deal with new issues or to think outside the box. A project manager described the massive impact of such an environment as

> *'the easiness is missing. And this lack of easiness somehow totally takes the fun out of the work, and I believe that if people had more fun, then the projects would also be more successful. And if that's missing, and I actually see that with many people I talk to now, that's a very crucial point. For productivity, for collaboration, for all the [innovative] things, that is a basic prerequisite.'*

In an extreme form, this high pressure can furthermore lead to intentional resistance to cooperation and to a competitiveness of individuals, which may seem rational in the short term, but in the long term is self-destructive for the individual and the organization. A business strategist summarized this phenomenom with its combined active and passive impact as follows:

> *'In this kind of environment it becomes much harder for people to collaborate because they think that their knowledge is the reason they're going to be kept here. So if they can be seen to be innovative, but they keep it to themselves, they can protect their position.*'

This extreme case of self-preservation instinct is probably not present consistently, however, typical for the industry is a self-interested basic attitude. Competitiveness and self-interested behavior is a phenomenon that historically has been present among stakeholders on construction projects and that is also found within the organization of the construction actor.

Self-Interest

Incentivized Corporate Fragmentation

A project manager explained this historical culture of self-interest grounded in the business concept of construction:

> *'However, this is probably also a problem of the business model: the GC is trimmed to take for his own benefit from his neighbors tablecloth.'*

A self-interested mindset is an integral part of the attitude and interaction of stakeholders on construction projects, where each player is intent on, and to a large extent finances their business by acting in their own interest and not for that of the project. A similar mindset prevails within the organization itself, between different departments, groups or even between individual employees. As one manager phrased it, 'people's mindset [is] more "how can I benefit from that?" than "what does it contribute to the group?"'. The origin of this attitude within the organization lies to a large extent in an incentive structure that promotes corporate fragmentation:

> *'It is certainly also a [corporate] problem, this silo thinking which is still around. Of course, it's fomented at the moment when success is attributed to individual departments. And that is logical, we're listed on the stock exchange. It will always be like that.'*

The consequence of this fragmentation, though, is a certain (informal) competition between internal parties. Managers consistently reported instances of trench warfare, limited collaboration, and 'a lot of effort to convince people to participate in other people's things'. As a business strategist pointed out, a solution to these problems is limited without the alignment of incentives, as one can address competitive thinking 'again and again through a lot of discussion, issue escalation, but it will never be perfect because the interests are different'.
For innovations, this problem exists to a similar extent, and becomes particularly relevant when innovations interfere with prevailing processes (Zwick, 2002). Consequently, the disruptive business innovation is predestined to cause competitive thoughts with existing business, as a business innovator summarized:

> *'The further you progress, the further you start to compete with traditional business of [the coporate], that of course is where it becomes tricky and you need to be more political, which is part of corporate innovation, but for some projects I can imagine it makes more sense to do that really next to or outside the current business. Otherwise you will keep on fighting for the same bits and pieces, and then you know who will lose: It's always the startup, because they have less resources and they need to fight against managers that already get paid double the price, they are already within the company for more than ten years and they will not give in. That's a bit the fight.'*

Selfish and competitive thinking thus can rapidly become a major threat to the implementation of innovations, which has been repeatedly proven historically (Christensen, 1997). A constructive relationship, in turn, would be of crucial importance for both innovation and in result the organization as a whole, as a business innovator pointed out in the context of IC:

> *'For [IC], you need full collaboration and a 100% commitment, otherwise you make a fool of yourself in front of the customer, and that is a risk I see with some of these initiatives, that we have to make sure if we promise, then we need to deliver. And then the game is on and it doesn't matter if you are in the division XYZ, you are [the company] and you have to deliver to this customer, and the rest is just side coffee talk so to say.'*

In order to address this self-interested and low-collaborative behaviour, participants described two mechanisms: One option would be the formal creation of incentives for cooperation and integration within the organization, which they assessed, however, as implementable only to a limited extent. A second approach would be an informal guidance of people through leadership, which, though, also occurs frequently in a rather fragmented form.

Leadership Fragmentation and Lack of Leadership

Talking about cooperation and competition within the company, one manager noted he

> *'think[s] it's human nature to see competition. And that's exactly where leadership [...] is needed, where you need leaders, not managers. It would probably also be naïve to believe that there will be an ideal world. There will certainly be conflicts.'*

One manifestation of these conflicts and rivalry is a 'positioning of individual parties on attractive competence areas of other parties' in order to strengthen their own position, as participants described in various cases. Avoiding such competitive situations, as one consultant pointed out, would be accordingly

> *'a question of leadership and strategy. People should understand what the strategy is, and somebody should be, when they're hearing these stories, should be saying, "Look, that is not your job, your job is this. You do your job, let them do their job. If you need what they've got, then go get it off them, but you should be doing [your job]."'*

Thus, participants concurred it would be highly desirable to establish more distinctive leadership, bringing people together constructively in their roles in a way that competition among divisions or between innovation and current business could be managed successfully.

Corporate Culture

Whereas competitive and self-interested behaviour represents one core component of the organization's cultural innovation barriers, a complementing set of cultural barriers appears in the historically conservative approach to work practices and processes throughout the industry, which is reflected in several divisions of the organization.

Conservatism

A project manager described the conservative mindset that he observed as a pattern that permeates the entire construction industry:

> *'In the meantime, I have developed the suspicion that this is not a [corporate] problem, but rather specific to the construction industry: there is actually no reason to question everything that works differently, is there? Building houses, for example, we can now optimize a little here and there, then there's BIM and so on - but we're actually still building with the classic methods and with what has traditionally worked.'*

Participants agreed that although not all divisions and employees share this mindset, the construction organization is 'still rather located in the traditional corner in many areas'. Consequently, 'probably a lot of people [] are not open for new things, [and] if that would be the case, [AEC] would be running like Apple', as a manager remarked.

In part, participants attributed this conservatism to the complexity of the work and the working conditions, as well as to a generation gap which, especially in the age of digitalization, gives rise to certain reservations among experienced staff.
Conservative reluctance, however, implies a difficult life for innovations as well as frustration and motivation loss for progressive employees, as a participant pointed out:

> *'I believe that many people are demoralized [...] and I think some people don't dare to do anything new anymore. So many are demoralized, that's what I've noticed. Of course, if you try to collect a budget for a topic ten times and it is cancelled again, you don't feel like knocking again for the eleventh time.'*

Participants further noted that the industry has been struggling with this conservatism to evolve for decades, regularly getting in its own way and caught up in its own idiosyncrasies. As a consequence, many of the participants assumed that the biggest challenge in the construction industry, especially for innovation, is anchored in the change of this culture, which was described as an extensive transition that will require a long period of time, as in this context, the industry's great deficits in progressivity, digitization and industrialization meet with change management processes that are hardly practiced in the economy yet.

Badmouth

As a result of self-interested way of working with little collaboration, the conservative stereotype of the typical construction actor and of competing working conditions, a number of participants described a further phenomenon, a culture of badmouth. During the study, participants described several issues where reservations and insinuations among different parties were rather at the core of the problem than the actual content of what was being argued. One manager, for instance, reflected this phenomenom while talking about the conservatism of the construction industry:

> *'You don't see people explicitly standing there with visions and ideas, but I haven't seen that in other companies either. In my environment, I don't perceive people as conservative, but people often tell me "they're stupid, they're stubborn, they're conservative", but I haven't had that experience myself and I don't believe that, to be honest.'*

Many criticisms about a lacking willingness to collaborate and a mutual lack of respect can furthermore be traced back to a lacking and improper communication between the parties. A project manager expressed that it would be quite helpful

> *'if [people would] communicate correctly, and [...] if you talk to people on an eye level and somehow communicate that with basic knowledge - I think it's sometimes also the inability of many and the willingness to want to communicate with people at eye level. It's because of both. It's not just the "grumpy" conservatives.'*

In conclusion, the collective impact of this three cultural implications of self-interest, conservatism, and badmouth add up to the first stream of innovation barriers from bottom up for innovation in AEC, which is complemented by a second stream resulting from a lack of communication.

Lack of Communication

The second main stream of internal collaboration barriers originates from a lack of internal information distribution, communication and engagement of the employees of the various divisions, which is in particular existent at lower levels.

One project manager described a communication environment that is heavily in need of 'more exchange, but at the operational level, [as] there [would be] a huge amount of knowledge that is not communicated at all or exchanged among one another.' A manager furthermore pointed out the synergies that get lost through this lack of information transfer as

> *'the group has a lot of expertise, doesn't it? So you [could] really build on experience, you don't have to start everything from scratch, you don't have to get everything externally. [However], new people keep arriving, and they don't know what we've already done, who sits where and with what competencies. And that is always difficult, because there is no system where you can call up competencies and see: "Ah, he has already done this and that, now I can put this together. " Few are now here [for decades] and have seen what we have already done. There's so much going on. And I don't have to start all over again every time. And that has something of a difficulty.'*

In fact, participants frequently mentioned little exchange of information and activities among each other. For instance, one innovator working on a new concept, described people sitting on the same floor who were working on similar projects, without the innovator knowing about that.

For innovations, being novel concepts and thus subject to limited understanding per se, this results in low awareness of the innovation by others and in result a risk of misperception and misinterpretation. Consequently, one stakeholder, when asked what success would look like for the implementation of an IC business unit, even described this success as

> *'internal know-how and also acceptance within the company of the products. And I think that at the moment [IC] is not yet working in the company because the topic is not yet established and accepted internally. We have to pick up a lot of players on the subject.'*

This needed communication, however, is not sufficient on a level of pure information, but rather it would be necessary to pick people up and engage them. As a participant explained, 'it's about involving people, not just sending them: provoking a dialogue internally', which would be the only way to 'show the future, to pick people up, what can the future look like'. In reverse, a missing involvement of people represents the root cause of bottom-up innovation barriers due to communication. As an innovator summarized, to encourage active collaboration and prevent passive resistance, the involvement of people is essential:

> *'Involving people, that really helps. Because in the end, everyone wants to be sort of part of new things, and either they are very excited, or they want to learn about it, or they are not sure about it or insecure. Then you need to show what you are doing, you need to explain what you are doing, so they can be*

part of that, and they are seeing “okay, we are not doing that” or “okay, we are doing that” and that can help them to, without pushing the project, they can still be part of the change.’

Lack of Internal Awareness

For innovations, a missing involvement of people results in an incomplete awareness of why these innovations are necessary, which for the specific case of IC is reflected in an fragmentary understanding of the concept, of the benefits for the respective individuals and the path to a realistic implementation of the whole principle. In turn, several participants described significant deficits in the internal awareness of topics such as sustainability, innovation and industrialization in construction. A manager even stated this lacking awareness as the biggest challenge for the development of the company’s IC unit in the short term:

> *’To transport the idea so that it is understood, that may sound absurd, but is probably the biggest challenge. [...] The understanding of the idea, that first has to grow in people, they first have to reflect on it. But I think it would be extremely important that the company understands the concept, in order to set the expectations correctly, in terms of timeline, in terms of success, perhaps also in terms of partial independence, which is also needed.’*

Benefits and Realizability

People’s awareness of positive impacts and personal benefits is further crucial for their acceptance and support, as one participant pointed out: ’When there are no benefits for the people, we have a huge problem with acceptance and this is a big danger for the success of the project.’ This applies in particular to innovations and changes that affect the respective people, and was consistently described as major risk factor for the successful implementation of these innovations. Even on a good communication basis, an innovation faces the problem that even if ’it’s not that difficult to demonstrate what’s in it for the people, this can only be proven or promised to a limited extent at the outset.’
Combined with the de facto insufficient communication base, an innovator summarized the resulting problem of internal unawareness for the implementation of IC as:

> *’That’s exactly the point: I don’t know what the commitment [of people] looks like, because I don’t know if they understand what [IC] actually does. It may well be that there is commitment for "what the [development team] is conjuring up there, and they are actually quite okay" and so they are now also giving a bit of credibility... but commitment that we actually want to bring a new offering to the market, and not new for the company, but new for the market, and that we are actually doing our best to ensure that this is successful, I don’t know whether there is commitment for something like that.’*

Another IC developer recounted in retrospect a similar picture of initial hesitancy of involved people for the then completely novel approach, which turned completely around when people realized the benefits and realizability of the concept:

> *'At first there was a rift maybe, there was some hesitancy to go into this more automated fashion, more digital fashion, [...] because it was something completely new for [the people]. Then once, as I said once they saw that it could benefit them and that they could build faster, they could build more projects, they could centrally scale to more projects and just be more efficient with the teams they had, then the teams became excited about it and they embodied and were empowered by it. Then they became a very close collaboration.'*

However, if internal stakeholders are not actively involved and taken along, it becomes difficult to motivate them and reduces the chances of cooperations and synergies. Even if there would be a willingness to collaborate on both sides, as participants described, often there appears to be no basis for collaboration because of a mutual missing understanding of how to implement that. One project manager explained this missing understanding base of people, hindering support and collaboration in the context of IC as:

> *'if you are just communicating [with management], you never get into the depths. [...] So often there is no common understanding. And that's why we really would need a case for implementation. At least only in theory, so that maybe the [people] understand the complexity a bit. Because if, for example, I somehow get a product suggested, then I say, "I think that's basically good, but we're already that far along in the planning [and] we are close to implementation". And then I don't see any way to implement an innovative concept. That's why we need, not only a very high altitude, but we need details, "what does it look like in the concrete planning, in the execution". So we need a theoretical implementation.'*

A lack of awareness, understanding, and sufficient belief, therefore, results in low collaboration and internal support for the implementation of the innovation, leading to the missed opportunity of a large potential of synergies.

Fear of Personal Losses

In the negative case, a lack of communication can furthermore become miscommunication and lead to a negative perception of new projects and their impacts. Change and innovation in general entail costly investments in human capital that are sunk (Zwick, 2002). In this context, inadequate communication and education of individuals provokes fears of personal disadvantages for the individuals and causes them to resist these changes. A number of participants reported the constant pheonomenom that there is 'always resistance from different people on projects - depending on who sees disadvantages in which areas'. This resistance was consistently described as depending on the level of the hierarchy, as a consultant summarized:

> *'Resistance is a human problem [...], people are afraid of change, afraid that they will be abolished and so on. The higher up in the hierarchy, the easier it is to convince people, because they quickly see the added value. The lower in the hierarchy, the more there is adherence to familiar processes, the greater the reluctance of people to change.'*

Depending on the perceived impact, the fear ranges from gentle hesitation and a lack of motivation in the face of unfavorable changes to massive resistance when people are afraid of major losses and see their jobs in danger. For this fear-related resistance, 'the utmost caution is required and [it] must be handled very carefully' - in contrast to the previously described lacking understanding of realizability or collaborative implementation, which 'is easier to eradicate through information and education'. According to the participants, this resistance would require a lot more personal involvement and convincing, since its 'only remedy is communication of transparency and added value', which for the people, who have a need for personal security, has to be demonstrated individually.
An industrial construction business model, for instance, implies changes in almost all areas of the business and thus actively impacts all involved stakeholders. In the course of digitalization and industrialization, an innovator summarized the consequences of this as:

> *'I think there's the people who will benefit from it, and the people who will lose from it. On average, the world will be a better place if we adopt modern methods of construction, but I'm not on average, I'm an individual. Some people will be better off, and they'll fit into this new world of collaboration and innovation and speed. Other people will want to work on 2D paper drawings, in a confrontational manner because that's the way that they've always worked in construction [...]. Those people will probably find this way of working very difficult.'*

As people agreed, these changes would have to be communicated actively and transparently and the stakeholders involved should be taken by the hand and shown a path to change, in order to avoid resistance and to benefit from the synergies arising by use of existing competencies in a collaborative implementation.
In the case of IC, roles such as the architect, the project management or the construction worker are particularly affected by major shifts in their job profiles and would need to be picked up thoroughly. As one IC developer summarized in retrospect, however, these actors, who although may intially fear the largest changes and sunk costs, can often be great beneficiaries of the innovation, if they understand the situation and are enthusiastic about the change:

> *'At first [the installation teams] were very timid, they were scared about [the changes]. Automation they think taking their job, but once they realized that we could empower them to put them in a modeling standpoint. They could build it virtually, then I think they became more excited. They became leaders and thought leaders throughout the company, throughout the industry which became a positive shift to see that happen.'*

However, if the people are not sufficiently involved, which according to the descriptions of numerous participants regularly is the case, individuals frequently react with resistance and the various parties conflict with each other instead of working together.

Lack of Support, Collaboration and Resistance to Changes

Concluding, from the bottom up, cultural reservations with a lack of openness to collaboration and change, and inadequate communication are the two main streams of barriers that actively and passively impede innovation. Breaking through this pattern of barriers therefore represents a joint task for those responsible for the innovation and their internal stakeholders. It is up to the stakeholders to maintain a certain openness to new and different ideas beyond cultural and work-related hurdles, as a project manager summed up:

> *'I think it's a willingness and perhaps also just such a serenity to accept new topics. Just to accept, to listen, not even to implement right away - and I find this prejudice a big obstacle. And maybe also the knowledge that it won't be that easy. With this attitude, you can also go somewhere.'*

On the other hand, it is the task of innovation to enable this openness, through communication, through education and through motivation, as a manager concluded:

> *'It's up to us to build up the charisma, to push this forward, [to bring people along]. And that what we do is like another [new great] business next door. If that's successful, then people come and they want to do that. "Is work, is cool, isn't it?"'*

Today, however, deficits are prevalent in both of these streams, which gives the barrier pattern its relevance for the development of innovations within the existing construction organization. As the participants described, 'in the end, there is always a fight in the company within the divisions and commercial units' and consequently the change resistance of people, a cultural change of the organization and the change management for innovation were classified by a large number of the participants as the biggest challenges facing today's construction actor.

3.6 The Market Readiness for Industrialized Construction

The third barrier pattern affecting the implementation of industrialized construction is situated at the external environment of the innovation. With IC, a concept implying for all market stakeholders major changes in processes which have prevailed for decades, meets an environment that is tailored specifically to these existing processes, and a market that has yet to become accustomed to industrialization. This incomplete *Market Readiness for IC* shows up in a further cycle, influencing the strategic opportunities of industrialization, the achieveable progress and the scalability of development and implementation.

The cycle, which is illustrated in Figure 3.5, begins with the strategic approach of IC, which encounters unprepared processes, low levels of digitization and standardization, and a lack of feedback cycles within the own organization. Within the value and supply chain, further constraints emerge in the collaboration with potential partners. On the one hand, the number of experienced players in manufacturing and industrialized concepts is rather limited, restricting the choice of partners and a large-scale offering of industrialized products. In addition, today's business culture of construction causes insufficient trust bases for long-term relationships and contracts among players, as would be necessary for industrialized business models. However, the main barriers of this pattern are located on the side of the market, of customers, builders and investors. Here IC encounters an incomplete awareness of the market for the concept and its advantages, as well as owners for whom IC represents a major mind shift in their culture of building, in their understanding of real estate and in the definition of their requirements. In addition, the regional attitude towards construction as well as an unaligned legal infrastructure hinder the implementation of IC, and again impair its strategic options.

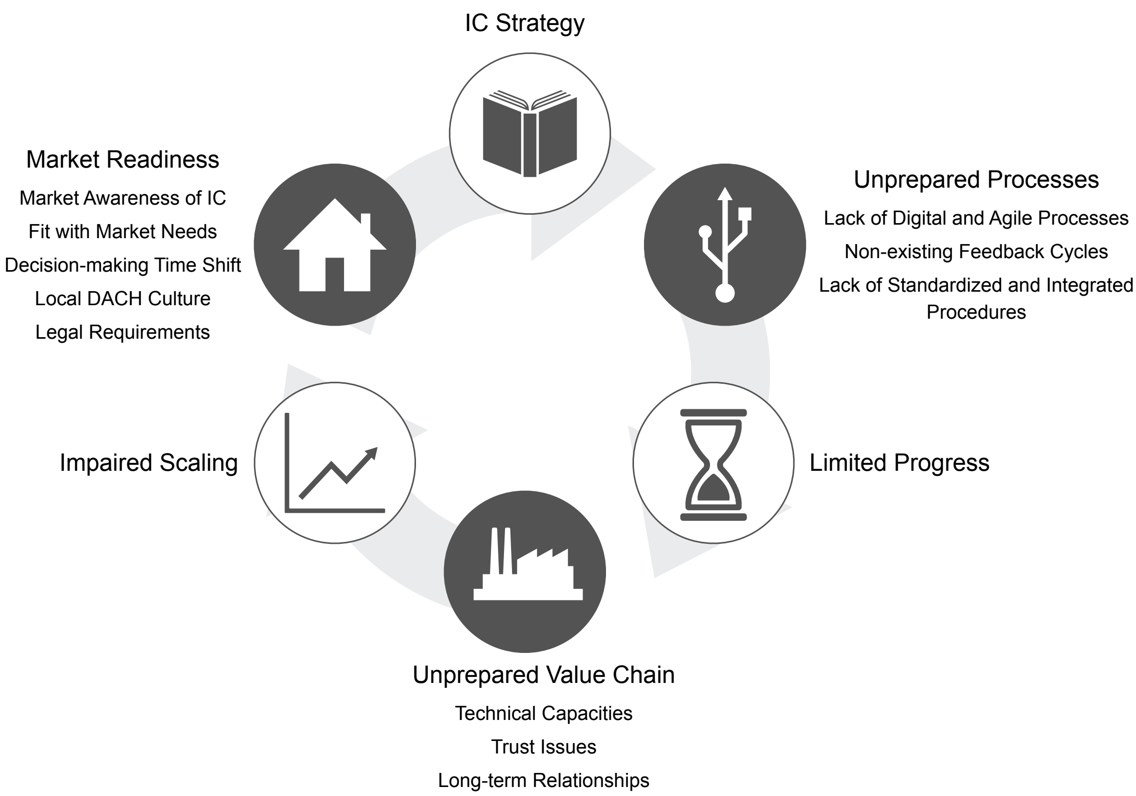


Figure 3.5: The Market Readiness for Industrialized Construction

Unprepared Processes

The first dimension of unpreparedness arises from the organization's processes, the business processes, the planning and construction processes, and a non-existent feedback and learning process.

Digital and Standardized Processes

An efficient implementation of IC is only possible on the basis of integrated digital processes for DfMA, project execution and interaction between the product platform and the individual projects. This digitalization of processes, however, is scarcely present in the industry yet (Manyika et al., 2015). During the study, participants described that although it would be highly desirable to 'digitize a lot more, unfortunately was not possible because [they rather] had to do groundwork on a large scale'.
This low level of digitization goes hand in hand with an immature standardization of processes and operations. Even without a shift to industrialized concepts, as people unanimously reported, a number of economies of scale and optimization effects are lost 'because [of] too little standardization internally. So we could certainly be better positioned in terms of resources if there were more standardized procedures', as a project manager noted.

Integrated Processes and Feedback Cycles

At the corporate level, this lack of standardization implies that the processes, technologies, and software used differ from project to project, and moreover within the projects leads to a fragmentation of information and knowledge among the different stakeholders. As one manager noted, however, especially for the implementation of IC, integrated standardized processes and procedures would be crucial:

> *'Another challenge [...] is fragmentation of information or technology. Where the exchange of information is different from each person and there's different technologies used, there's different software used by every project, every entity. It's always this learning curve and this opportunity for waste or error. If that can be streamlined and that can be standardized as well, whether it's the data exchange or whether it's the software use, the type of modeling used. I think that can lend itself definitely industrialized construction. Because it's all about the process.'*

Fragmented and diverse processes, in turn, cause the problem that mechanisms for learning from the individual projects can only be implemented to a very limited extent. These feedback loops, however, represent a core pillar of IC, without which, as the participants agreed, an economic scaling of IC hardly appears possible. One manager described this learning inability in today's business as a lack of professionalism of construction:

> *'The problem comes back to the project business. If a project manager does a major project, then he is immersed for three or four years. And actually, you would have to have a professionalization after this phase and optimize*

these processes, that you do the same thing over and over again, that you can drive it further. And we have to change the processes in parallel [during the projects] and make sure that we build that up as well. We can't slip back into old, classic procedures. But the question is: Are there people who can do this? This has nothing to do with [the company], these are general industry issues. It's not that [we] don't have particularly good people, we might even have disproportionately good people, but even with them it's not easy. Construction remains a rather modest professional business. Sometimes more, sometimes less.'

Process fragmentation starts within the organization and continues between the various project participants along the entire value chain, from planning to execution and operation of the buildings.
As the participants mentioned, a key success factor for the implementation of IC consequently would be an 'exact calibration of all processes of the overall concept' - though standing in sharp contrast to today's common procedures, which in turnrepresent the first barrier of the circle and slow down the pace of an IC development.

Unprepared Value Chain

The organization's environment is to a limited extent prepared for industrialized concepts as well. A productization of buildings is based on integrated planning, manufacturing, logistics and assembly, all of which must be closely coordinated and function as a composite.The challenge hereby lies in the necessity for all these tasks to function as an integrative entity, which requires a smooth interaction with all partners of the entire supply chain, at a scale that allows the concept to be economically efficient. A manager described this task as:

'that you can quickly find opportunities where you can build properly, [...] so that you can really bring several hundred rooms or units per year to the market. And before you can sell it to third parties, to also define a pricing, to also have a low-cost production [...], and that everything then works together, including the logistics. It can't be traced back to one point, in other words, that this concept simply works integrally, that's really the big challenge.'

For a cooperation with partners along the value chain, this poses two problems: On the one hand, there are only a limited number of players offering industrialized manufacturing concepts. Moreover, the level of industrialization among these players is also limited, as 'the sophistication is still very low in modern methods of construction. What that means, if I've got a factory today, the process is still quite manual', as an innovator marked. Furthermore, the companies in question currently do not have much experience yet and it is thus uncertain whether partners are suitable for successful cooperations in the long term, as participants pointed out. Crucial in this context would be an open attitude of potential partners, being 'dynamic and willing to invest time and resources in this industrialization, [as their] mindset is perhaps even more important than their current competencies and skills'. As a manager explained, the development of industrialized products moreover requires time and will thus only be possible on the basis of long-term collaborations:

'It will take time and that's why you have to make framework agreements and then grow with each other, just as the product is permanently adapted, so there has to be some kind of interaction, [...] we have to make framework agreements. We can't just tender every project individually and always cooperate with the one who offers a discount of five thousand, that won't work.'

Long-term contracts, though, would have to be based on a collaborative and partnership basis, as participants agreed. It would be necessary to 'move away from simple volume and lowest price to a more collaborative approach, actually trying together to optimize and reduce costs by optimizing the module, the product'.
However, such partnership relationships oppose the current contractual cooperations of construction actors, which are organized on a short-term basis for individual projects and are characterized by mistrust and the self-interested behavior of actors described in Section 3.5. Being used to today's experience of cooperation, for the involved parties a shift to collaborative long-term relationships would mean a huge change in mindset, mutual cooperation and communication. Consequently, participants agreed that there is no sufficient trust basis for long-term relationships between actors yet and that a lot of initial persuasion work will be necessary to overcome these trust issues between the various actors.

Market Readiness for IC

The most significant barriers of an unprepared environment, however, relate to the market readiness for industrialized concepts. Here, IC encounters a lack of readiness on almost all levels of external stakeholders: customers, owners and investors who do not have a comprehensive awareness of real estate products, as well as reciprocal construction players who require more understanding of the demands of their customers for these products. A construction culture that is scarcely progressive in the DACH region and a norm of planning alongside construction, with a definition of the client's needs as late as during the project execution. And a legal and regulatory infrastructure which is aligned for building prototypes and scarcely compatible for pre-defined real estate products. Thus, as one participant indicated, the first step in the implementation of IC will likely need to be a push business model of the IC actor to initially introduce the market to the concept:

'How do you get the market out there? I don't think it's deceptive that it's more of a push business model. So you go out with that and try to develop the market. On its own, I don't think it can be done that easily. And that's why it's important how you can [convince] the building owners, planners, spatial planners, by the way, that goes all the way to the authorities and so on. [...] You [may] find some interested parties, builders, who want to develop in this way, that exists. But we're talking about a market worth billions here, aren't we? [...] And for that, of course, it needs a lot, a lot, a lot of market shaping, you almost have to say.'

A first step in this direction, according to the participants, is an education of the market to generate an awareness for industrialized building concepts, including a demonstration of their benefits.

Awareness of Industrialized Construction Benefits

As a market expert described, today's market awareness is rather limited and raising this awareness will not be an easy task:

> *'There are a few who already know about the benefits, there are a few who you can easily convince, then a large mass that you have to convince with huge effort and a few who you will never be able to convince.'*

The lack of awareness begins with consciousness of the need for optimized and more sustainable building concepts. As one investor described the current standing of innovations in the market, in many cases there is an

> *'"explosive thinking" about new things: it's not about what you can really implement, what that means, but about the press release: we're the first to do it, we want it exclusively, the media announcement, and then it's good, no matter what it actually is... and of course, you can't implement an innovation that way.'*

As participants pointed out, this lack of thirst for innovation originates from a profitable past of the real estate market, thus showing no active interest in applying and investing in unfamiliar, higher-risk concepts. In addition to that, the market still encounters low external pressure for more sustainability, despite the major impact of AEC and real estate on the environment. A decisive factor for establishing industrialized concepts on the market is therefore the creation of awareness of the need for innovation and, in turn, a demonstration of the advantages that IC provides, as an innovator resumed:

> *'I think the largest thing is just the shift [of] the client standpoint, showing them the value [...] and convincing them that this is the way to go, and showing them why that is valuable. It seems like more of a client driven process.'*

Market needs

This key success factor of convincing the market of IC concepts is based on the condition to precisely understand the respective needs of the customers and align the IC offering accordingly. This precondition entails two problems, as participants pointed out: the conventional principle of building with a GC is configured for a construction process of already specified requirements and thus focuses only to a limited extent on the customers' demands. In contrast, a hollistic customer orientation as required for IC, thus is a core competence of the construction actor, which he has to acquire yet. A project manager described the lack of customer knowledge as an 'old problem [of the industry]: historically, [you follow an] inside-out principle, you are completely convinced of what you are doing and neglect the customer's point of view.' Hence, a barrier for IC consists in achieving a fit with the market needs of the customers, which the construction actor only has limited knowledge of. Even more, with IC a situation occurs where customers, who are not familiar with real estate products, furthermore yet do not fully recognize the benefits of these products as serving their needs, as an expert explained:

> *'We can certainly assume that customers, both investors and users, have a need that is changing in a direction that we can satisfy with real estate products. However, I cannot judge whether they are already aware of this today.'*

Consequently, as participants explained further, the changeover from pure price competition, as is common for today's construction as a service, to a consideration of price-performance ratios, which constitutes the sale of products, represents a major mindshift on top of that, which will be even more challenging to achieve market acceptance for.

Local Culture

A barrier for the *scaling speed* of IC is situated in the regional building culture, which prevails in Central Europe and particularly in the DACH region to be rather conservative. A manager described the importance of culture on the scalability of IC as:

> *'Construction is extremely influenced by culture, isn't it? That's the way it is and it will always be, it's ingrained in people's minds. I think Katerra will succeed in America with their [broad] approach because they're doing it in an American way. America is a little bit "go in, drop the bomb, and then see what happens," right? But that's not the [European] approach, and it wouldn't work here either. It would encounter far too much resistance here. Here it's really like, you start with a needle, with a certain level of perfection, and then you expand that.'*

A manager further described the DACH region's building culture and its influence on the acceptance of standardized products as:

> *'we [...] are a bit behind, I mean Holland is much further ahead, the Nordics are much further ahead, Australia, the Asians, the Americans, they are much more open. I think in Switzerland we still have a tendency to build once and for a lifetime, not just in terms of single-family homes, but in general, and that leads to an exaggerated sense of one-offs.'*

According to the unanimous opinion of the participants, a scaling of IC will therefore not be possible in the DACH region as quickly as in countries with a more progressive attitude towards construction. Thus, it rather will be necessary to convince customers with several individual pilot projects, and to approach the implementation of IC step by step before scaling up.

Legal requirements

In addition, the regulatory infrastructure for construction, in line with the local building culture, is neither suitable for innovative concepts in general, nor for standardized real estate products in specific. As participants unanimously described, 'especially in the public sector [] we are tied to our hands' when it comes to offering industrialized solutions and predefined products. One manager described the regulatory and code infrastructure as:

> *'The associations and the standards system and the building codes, they go completely against the idea of standardization. You have to create architectural quality and you can't take something out of the catalog [...], that's completely a no-go.'*

Consequently, an additional barrier is located in a need for conversion of construction regulations, public procurement law and construction standards. However, according to several experts, this conversion is to some extent hindered by the building culture described above, which strives for individual architecture rather than standardized products, and complicates the implementation of IC by the fact that the concepts, at least for today, must initially be developed along rather incompatible building codes.

Time Shift of Construction Target Definition

A final obstacle on the customer side is located in the time shift of their construction target definition. Even if customers are convinced of the advantages of industrialized products, these require early design freezes and thus a significantly earlier commitment of the customer to his desired solution (compare Section 2.4). This contrasts with the current way of construction in the DACH region, where large parts of the design are completed just during the construction phase and a multitude of modifications are carried out within the project execution, thus representing a major mindshift for the client, as an IC innovator summarized:

> *'Then when it comes to actually implementing, the question is, is that client, is that design team [...] prepared for the process to do it? Essentially are they able to make decisions upfront? If you're using a digital fabrication, building in the model, are they ready to essentially build a building virtually in a 3D model, lock it, sign off and say "this is what we're going to build", so they can send it to the factory. Versus being used to the normal process of change orders onsite and last minute changes - which doesn't work. You don't see the cost effectiveness of pre-fabrication, industrialized construction in that standpoint. I guess the question is, "is that entity that's building the building, doing the project, are they ready to make decisions up front in that sense?" Which created a whole new process for a lot of people, because [it] wasn't really status quo at the time. That needed to change. It was really shifting the mindset that the model was truly a locked in model to be fabricated from at that time.'*

Conquering the Market

This incomplete *Market Readiness* finally complicates the development of IC, slows its scaling, and conversely limits the strategic options for an implementation. However, a big advantage for addressing the market barriers for the existing construction actor could be, as participants emphasized, the existing market penetration and reputation of the organization, which has the potential to be a driving factor for convincing customers and weaken the prevailing building culture.

Ultimately, though, a key tipping point probably will be the market's awareness of the necessity for sustainability and change in construction, which is likely to increase over the next few years, as soon as external pressure on the industry and the market intensifies. Once initially stimulated, it is likely that the market acceptance and appreciation of industrial concepts will begin to snowball and the prevailing building culture will open up to optimized and strandardized concepts, to the next normal in construction.

Chapter 4
Discussion

Industrialized construction concepts have the potential to solve the struggle of the construction industry with productivity and profitability and to evolve AEC towards a sustainable future. For a broad implementation and an adequate impact of IC, however, it becomes necessary that, in addition to new players, also existing organizations adapt their current business and implement industrialized methods and solutions. However, industrialized construction, implying much more than just prefabrication, differs significantly to today's construction operations and implies major transformations in the current business, mindset and way of working for the existing actor.

There is not *one* universal concept of IC. Rather, a wide spectrum of promising industrialized strategies within a broad range of scopes can be observed and it is not to be expected that there will be a predominant player or concept prevailing internationally (Ribeirinho et al., 2020). What all these approaches have in common for the existing construction company, however, are comprehensive changes in all areas of its business model, transforming the entire prevailing concept of construction and transferring large parts of the real estate development from a project level to a corporate level: The implementation of product platforms enables project-independent planning and manufacturing of pre-defined elements, thus requiring a shift from individual project processing to long-term expertise and collaborations. Associated pre-specifiaction of the offering and a conversion to the sale of products presuppose a comprehensive customer orientation and a business focus on the market and its needs. Furthermore, significant upfront investments during development and high efficiency gains later on during platform operation necessitate a shift to cost accounting based on product series, rather than individual projects.

For today's industry, IC thus represents a comprehensive transformation that requires the joint implementation of a whole range of construction innovations, from large-scale integration of processes and entities, via end-to-end standardized digital planning and documentation procedures, to automated and industrialized manufacturing, logistics and assembly methods, all of which have to be harmonized and function as a collective. Consequently, these extensive changes in product, processes and business model give the concept of industrialized construction the character of a highly disruptive business innovation.

For the existing actor who wants to implement IC, a transformation of his conventional business further entails a number of barriers from his environment that impede his strategic options, his progress in development and the possibilities of scaling. A direct investigation of these barriers in the context of a case study revealed a series of implications that largely take place at the soft corporate dimensions and can be grouped into three barrier patterns, which emerge in the interactions of the innovation with its internal and external stakeholders of the organization and within its environment. The patterns add up to a narrative of an industry shaped by its harsh economic conditions, trapped in a culture of risk aversion, limited openness and little collaboration, and a market unfamiliar with industrialization, in whose building culture the latter has yet to be established. Despite the limited generalizability of single case studies, the results of the study are consistent with existing literature and the assessment of experts, which gives some reason to assume these patterns to be less company-specific but representing rather industry-wide problems. Further, these barriers, which are situated to a large extent in cultural change and a mindset transformation of the industry, are unanimously described as even more challenging than the actual development of IC. It therefore remains to be shown how quickly and extensively the existing industry will be able to adapt, and whether the industrialization of construction will be more a transformation of the current industry, or rather gives rise to a new industry, over time replacing the present one.

In summary, the aggregate task of industrializing construction represents potentially one of the most comprehensive and challenging changes for AEC in recent decades, but also the one with the highest impact.

Chapter 5
Conclusion

This thesis examines IC on an organizational level from the perspective of today's industry and the conventional construction actor. It highlights industrialized construction in comparison to conventional construction and addresses the questions of how the construction company's business differs across these concepts and which challenges the company that tries to adapt their operations and implement an IC business model is facing. Herein, it describes the differences in strategy, process and business models and, in an analysis of the implications of adopting IC, identifies three innovation barrier patterns that hinder an implementation within the existing construction environment.

5.1 Contributions

Contributions to Theory

This research joins a small but growing body of IC literature from an overall organizational perspective. While IC is comprehensively described from a technical and manufacturing perspective (Gann, 1996; Gibb, 1999; Haas et al., 2000), research from an organizational and business point of view is rather limited (Brege et al., 2014; Lessing, 2015) and especially knowledge about change management and the implications of such business model innovations in the construction sector is quite scarce (Liu et al., 2017). In this context, the thesis proposes an organizational change analysis for IC to improve the understanding of IC from a business perspective, and the external and internal mechanisms and implications of IC as a BMI of the existing construction actor. In doing so, the thesis contributes to research by framing the variety of industrialized construction strategies, processes and business models in conceptual scaffolds, relating them to conventional concepts and thereby elaborating the changes in business that are necessary for the transformation to an industrialized approach. Furthermore, it explains the implications and mechanisms of the relationships between innovation approaches within existing construction organizations and their stakeholders and creates a detailed understanding of three specific barrier patterns for the implementation of IC, that hinder its development as a BMI.

Contributions to Practice

As IC has been trending and gaining ground in recent years, a number of established construction companies can be observed attempting the development of industrialized business models. For these actors, the thesis proposes a roadmap for embarking on the journey of this business model innovation. On the one hand, it gives a baseline on how industrialized construction can be approached and which differences this implies in comparison to the conventional construction business. Furthermore, it gives an idea of the challenges to be expected when undertaking this journey and thus contributes to the IC innovator's understanding of the barriers affecting him within his environment, and to the organization's understanding of internal mechanisms and implications for its management of innovation and change.

5.2 Limitations

The research faces limitations in specific applicability and generizability. The first limitation relates to the purely conceptual description of IC in its hard business categories of strategy, processes and business models. In the attempt to frame the broad domain of industrialized construction, the proposed conceptual scaffolds give an overview of theoretical and methodological differences of the industrialized and conventional way of construction, however, can be applied to a rather limited extent for a specific implementation approach of IC.

The second limitation is generalizing the identified IC innovation barriers to other contexts. These are largely based on the single case study of a large swiss construction company in an early development phase of their IC initiative, and although they are mostly consistent with the descriptions in published literature and by external experts, it is possible that certain phenomena are specific to the environment of this case company. Thus, some of the findings may not hold for other IC business transformation approaches in different stages of their development, different company environments, or other regional origins. Although the problem of generalizability has been addressed with an abductive case study approach and a continuous cross-check of the single case study with external experts in business innovation and IC business development, and the latter argues for a certain generalizability, this remains an issue to be explored in further research.

5.3 Further Research

The implementation of industrialized concepts offers significant potential to dominate the performance of conventional construction (Bertram et al., 2019) and become an essential concept of the future of construction (Ribeirinho et al., 2020), thus opening a wide spectrum of further research in this domain.

In direct relation to this thesis, an extension of the single case study enables a range of further insights: An investigation of the IC case approach over a longer period of time enables the examination of development and impact of barriers over time and provides insights into how they are dealt with. Extending the study to multiple case companies allows for an evaluation of the benefits and drawbacks of different IC strategies and a comparison of these. The examination of innovation barriers of several diverse approaches provides further evidence about the generalizability of the identified barrier patterns as well as potential KSF or best practice for their addressing. A polarizing issue in this context, which might be of particular interest for further resarch, is the decision on intrapreneurship or entrepreneurship, of developing the IC business within the company versus separating it from the rest of the organization. While both of these options provide

pros and cons, a clear preference of literature, history and expert opinion for separation of the disruptive innovation approach contrasts with a number of enterprises that refuse their innovation units this leap of independence.
Furthermore, an investigation of the regional building culture - as identified as a significant factor for the scalability of IC - is worth further research for revealing insights into cultural differences and framework conditions for IC, for instance, in comparison of Europe and the United States.

Beyond this case study, moreover, IC research to date is just at the beginning. One perspective that has hardly been addressed in IC research yet is that of the real estate industry. In many cases, however, the development of real estate products resides closer to real estate development than it does to the construction business. Industrialized construction further addresses not only the horizontal, vertical and longitudinal fragmentation of the AEC industry (Sheffer, 2011), but also has the potential to extensively affect the fragmentation of the real estate market. Industrialized real estate products that can be standardized across market segments and regions offer the opportunity to bring transparency and consistency to a highly imperfect real estate market (DiPasquale & Wheaton, 1996) with its typical regional (Goodman & Thibodeau, 1998), sectoral (Adair et al., 1996) and cyclical (Wheaton, 1999) high levels of fragmentation.
Finally, the investigation of catalysts for the implementation of IC constitutes a further major research subject. Thus, there is great value in a more precise understanding of the "catalyst capability" of IC supporting processes such as end-to-end BIM, lean construction methods or early contract involvements as well as external events that represent "tipping points" for a broad industrialization of the AEC industry. For example, a major boost can be expected among others from a rising awareness of construction as major impact on global warming and the environment, or regionally from a provider succeeding in delivering industrialized buildings cheaper, faster and of higher quality than conventional ones in large quantities and with high reliability.
Last but not least, the current situation calls for an investigation of the impact of COVID on the attitude towards construction and the demands on buildings, and the effects of this on the implementation of industrialized concepts.

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Appendix A
Interview Questionnaire

Attached below is an excerpt of the questionnaire used for the case study conducted in Chapter 3. The interviews were scheduled to last 40-80 minutes and were conducted partly in German and English language, either in dialog on site or via video meetings. Due to the semi-structured concept used, the exact questions of the individual interviews have been adaptive and deviated from the basic concept as appropriate to the situation. According to the abductive principle of the case study, the interview questionnaire furthermore was continuously revised and adapted to the combined findings from previous interviews and literature. Thus, the following questionnaire represents only an excerpt of the questions that were discussed in the individual interviews, which was then modified, expanded or adjusted flexibly in the individual discussions.

General

- What do you think of when we talk about the concept of "Industrialized Construction"?
- How would you assess the concept? Is it just a trend or the future of construction?
- How do you estimate the implementation rate of IC in the short and long term?
- How would you define success for an IC disruption approach?
- If you were responsible for the IC initiative, what would keep you awake at night?
- What are the biggest technical challenges in ramp-up and scaling phases?

External Barriers

- What is the customer attitude towards IC concepts? Are they aware of benefits and implications?
- What are the big problems in the development of IC with the value chain?
- How should one approve such a transformation and disruption? With individual pilot projects or rather in a broad initiative?

Internal Barriers

- How can the IC approach benefit from the organization?
- Where does the organization hinder the approach?
- How to manage internal conflicts / competitions with other departments?
- Would it make more sense to separate the initiative from the corporate?
- Do you sense a lot of resistance to change within the organization?
- How do you encourage people / Have you been encouraged yet to support such novel developments and innovations?
- Do you think there is enough commitment for such initiatives?
- Do you see increasing awareness in the company of the need for change and improvement?
- Are people ready for disruptive changes?
- Should the organization spend more on innovation?
- How do you handle bureaucracy and inflexible processes within the large organization?