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DIGITAL TRANSFORMATION IN CONSTRUCTION – A REVIEW

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SUMMARY: *Digital transformation (DT) is expected to contribute to the construction industry's ability to meet climate and sustainable challenges and increase companies' productivity. This study aims to explore requirements for, and factors affecting DT in the construction industry. This research goes beyond the technology perspective and focus on factors needed to transform the potential of digitalisation to benefits for organisations in the construction industry. A structured literature review is performed where knowledge gaps are identified, and a framework is developed that maps the required changes, as well as the associated challenges, constraints, and implications.*
The construction industry´s business-to-business logic, and the fragmented and project-based structure is found to have impact on the industry´s development within DT. Mainly regarding the DT aspects disruption, structural changes, organisational barriers, and the central aspect value creation. The understanding of DT by scholars and practitioners in the construction industry is found immature and this calls for further research. The research contributes to understanding of the concept DT and proposes, based on earlier DT literature, an adjusted framework for DT in construction, and points out key areas where research in construction has gaps to fill.

KEYWORDS: *Digital transformation; Digitalisation; Construction industry; Review; Value creation; Framework*

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1. INTRODUCTION

Information Technology has been increasingly developed and implemented in the construction industry for several decades. Several surveys targeting construction indicate a strong focus on technologies that can enhance companies' internal efficiency (Howard et al., 2002; Acar et al., 2005; Chien & Barthorpe, 2010; Samuelson & Björk, 2014). They have shown that common tools designed to facilitate communication, financial tasks and administration have been implemented at pace with the general development and spread of digital technology in society. However, there have also been developments in the core construction functions and operations. Of these, the introduction of Building Information Modelling (BIM) has probably most profoundly affected stakeholders.

In other industries, such as manufacturing, digitalisation has developed further than in construction, and has had such profound effects, as described by various authors (e.g., Nissen, 2017; Parida et al., 2019), that the term Digital Transformation (DT) has been widely applied. This refers to overall changes in products, services, processes, business models and value chains driven by digitalisation, and associated challenges that companies are facing to exploit the opportunities offered by new technologies (Matt et al., 2015). In a review of 282 DT studies, Vial (2019) concluded that it involves profound changes in firms and societies, and that firms need to innovate using digital technologies to adapt to associated changes in their ecosystems. Thus, the concept DT encompasses much broader changes in firms' business than merely the introduction of IT or increases in use of IT.

The term DT has also begun to be used in construction, but there are few indications that such radical change has really occurred in companies or common processes of the industry. The industry is fragmented with numerous companies that collaborate in many projects that involve participation of agents with diverse backgrounds and specializations. There is also sharp separation between design and production phases (unlike processes in most other industries), and the specialization in different disciplines in both of these phases contributes to sub-optimal deliveries in the process (Nawi et al., 2014). In order to manage projects despite the fragmentation, clear roles, processes, and project organizational structures have been established over a long period of time, which facilitate communication and the contractual relations between actors, but also inhibit changes in the structures. In such contexts, DT must involve profound innovations and changes in multiple organizations' operations, structures and processes, but instigating such changes is clearly beyond any single organisation's sphere of influence. This is discussed by Harty (2005) in terms of bounded and unbounded modes of innovation.

Considering these characteristics, i.e., a fragmented industry, based on collaboration in project, where design and production is separated, and where changes in structures often goes beyond the control of a single organisation, research is needed to elucidate the challenges and constraints associated with DT in the context of the construction industry. There is a risk that DT, which requires extensive changes in business logic, will by-pass the industry or at least be severely hampered by the industry's inability to change quickly.

Thus, to assist efforts to realize the benefits, this paper explores the requirements for, and factors affecting, DT to be considered in the construction industry, based on a systematic literature review. There are many different types of digital technologies that are used and could be used by the construction industry's various companies. This paper does not focus on the individual techniques, which are one of several aspects of DT; it rather focuses on the general factors and aspects that the change of DT entails. The central aspects of DT are described and compared with insights gained to date on DT in construction in efforts to identify the most important knowledge gaps and develop a framework that maps the required changes, as well as the associated challenges, constraints, and implications. The following research questions (RQs) have been formulated to assist efforts to meet these aims:

> RQ 1: What are the specific conditions in the construction industry to enable DT, in relation to central aspects highlighted in the general DT literature?

Having identified such conditions:

> RQ 2: What should a framework for DT in the construction industry include?
>
> RQ 3: What aspects require further research to support the construction industry realise the benefits of DT?

2. DIGITAL TRANSFORMATION IN A CONSTRUCTION CONTEXT

The main theoretical framework of this study consists of key concepts regarding DT and both the structure and business logic of the construction industry, which must be understood to address RQ1. However, it has also been

extended as necessary to address RQ 2 and RQ 3 in accordance with the findings obtained from addressing RQ 1 (as described at the start of section 5).

2.1 Digital transformation

DT has received intense attention from scholars in recent years, not least because of the need for a strategic approach (Matt et al., 2015; Kane et al., 2015). Various reviews have been published on the subject and the one by Vial (2019) was selected to provide foundations for this study as it is the most comprehensive published to date. The cited author evaluated 23 proposed definitions of DT from 28 sources, presented his own definition, and formulated a theoretical model of DT (Fig. 1) based on a detailed review of 282 articles.

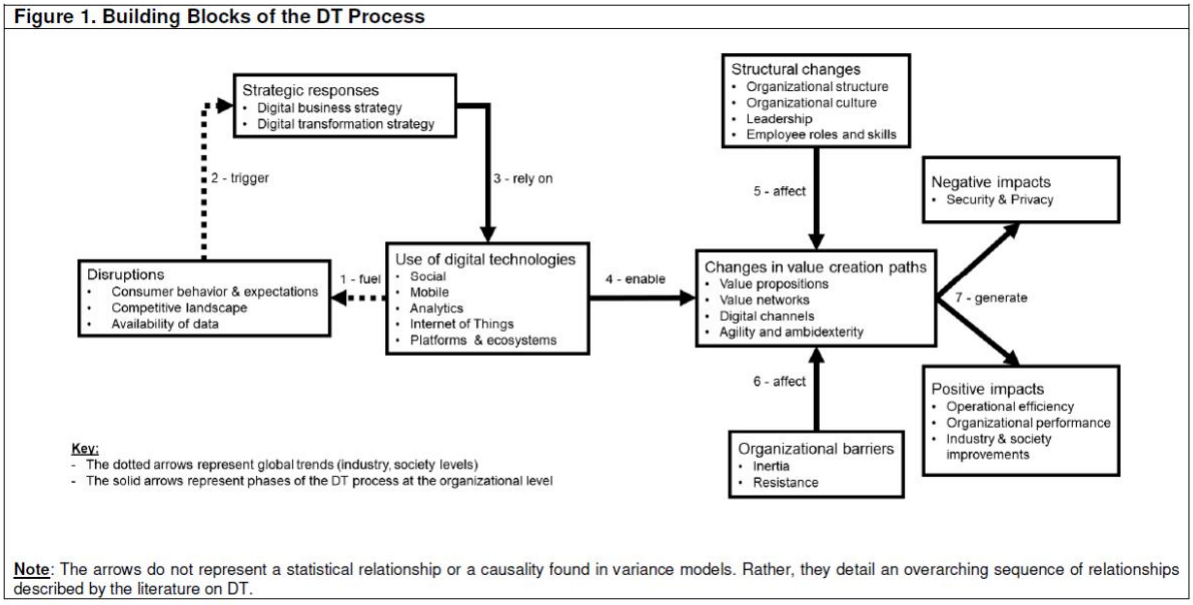


FIG. 1: Theoretical model of the Digital Transformation Process (Vial, 2019)

Vial (2019:9) analysed the proposed definitions of DT found in literature and stated that the definitions have shortcomings that hinder conceptual clarity. He identified three types of shortcomings (circular reasoning, unclear terminology, and the conflation of the concept and its impacts) then formulated the following working definition of DT:

> "*a process that aims to improve an entity by triggering significant changes to its properties through combinations of information, computing, communication, and connectivity technologies*".

An important element of this definition is that it does not refer primarily to organisations, instead the term "entity" is chosen. This is useful in construction research as it does not restrict consideration to organisational-level phenomena and potentially encompasses an organisation's environment or network. In addition, the definition includes general terms such as "improve an entity" and "significant changes" without describing the types of improvements or significant changes involved. This was a conscious choice of Vial, resulting from criticism of the analysed definitions.

However, since "significant change" in the construction industry is hindered by its structures, as discussed for example by Dubois & Gadde (2002), it is useful to understand the nature of the changes needed for DT. In the definitions studied by Vial (ibid.) there are three recurring and apparently crucial types of change. These are changes in organisational structures, processes, and business models.

Vial (2019) constructed a theoretical model based on empirical data from the literature review, described as a "DT process model", consisting of eight building blocks and seven arrows indicating the blocks' relationships with, and effects on, other blocks (Fig. 1). In this paper we consider the model conceptually and focus on the meaning of the constituent factors, rather than as a process. A block called *Use of digital technologies* in a central position in the model is based on the SMACIT (Social, Mobile, Analytics, Cloud and IoT) acronym (Sebastian et al., 2017).

The model suggests that *Use of digital technologies* creates and reinforces *Disruptions* on different organizational and society levels that trigger *Strategic responses*, which affect *Use of digital technologies*, thereby constituting one loop in the model.

The *Use of digital technologies* enables *Changes in value creation*, value chains and business models. Uber, Airbnb and Spotify are frequently cited examples of companies that have created disruption with the help of new values and business models (Skog et al., 2018). The *Changes in value creation* are affected by the abilities to implement necessary *Structural changes* and overcome *Organizational barriers*. The changes are supposed to have *Positive impacts*, but there are also possibilities of *Negative impacts* that must be addressed.

According to Vial (2019), elements of the proposed model should not be viewed solely from an organization-centric perspective but also from individual-, industry- and society-level perspectives. This is particularly crucial when addressing the construction industry, and its project-based structures.

A research area closely linked to use of new technologies is innovation implementation and adoption. Within the framework of this research, it has been considered interesting to reflect on how literature on implementation and adoption relate to DT. More than 50 years ago, seminal work was published by Rogers and summarized in a later publication (Rogers, 2003), on the spread and implementation of innovations. Rogers (ibid) also provided the "S-curve" showing the time course of adoption of innovations by five groups of adopters (innovators, early adopters, early majority, late majority and laggards). Various models for technology acceptance, including digital technologies, have been subsequently developed by Davis *et al*. (1989), Venkatesh and Davis (2000) and Venkatesh *et al*. (2003).

These models primarily focus on individuals in organisations and preconditions for users related to their professional roles and tasks. However, the factors included in the models are generic and can also be applied at organisational and project levels, as shown by Samuelson and Björk (2013). Gallivan (2001) points out that adoption decisions are made at organizational or workgroup levels and proposes that organizational adoption and assimilation of innovations should include organizational and individual levels.

More recently, Succar and Kassem (2015) have focused on adoption of BIM and noted that dissemination of innovations (e.g., BIM) needs to be handled at multiple levels, such as individuals, groups, organizations, project teams and whole markets. Succar and Kassem (2015) propose a distinction between implementation and diffusion. *Implementation* is described as the successful adoption of a system or a process by a single organisation and *diffusion* as the spread of the system or process within a population of adopters, where a population can represent a whole market. In this paper, the terms are used according to this distinction.

2.2 The nature of the construction industry

To understand the requirements for DT of the construction industry it is essential to describe and understand the industry's characteristics. The organization of the construction industry is widely documented in the literature. Common published characteristics that affect companies' abilities and incentives to change on company, project and industry levels are summarized below. They are largely drawn from innovation literature, since the need for change described in DT literature is considered to be tightly connected to innovation processes in companies and industries.

The industry is largely project-based (e.g. Slaughter, 1998). In subsequent projects there are new constellations of companies and individuals, which impedes transfer of knowledge and development of common working methods over time (Reichstein et al., 2005). Dubois and Gadde (2002) argue that these types of loosely coupled systems can be creative and innovative in solving current problems, but hinder diffusion of innovations at the industry level.

Several aspects of the industry's fragmentation are highlighted in the literature. The high numbers of professions and organisations involved in projects cause problems with integration and coordination of the stakeholders (Nawi et al., 2014). In addition, there are large numbers of small companies in the industry with little innovative capability (Reichstein et al., 2005). The few large contractors that operate in each country are heavily dependent on all the small subcontractors, which hinders industry-level innovation and development. Unlike other industries, design and production are usually separated in construction (Groak, 1994; Koskela, 2003). This separation also prevents,

or at least greatly hampers, systematic transfer of knowledge and experiences acquired in the production phase to the designers to continuously enhance the working methods.

In addition, innovation processes may occur at different levels in the construction industry with profoundly differing features, in (for example) drivers, barriers and benefits (e.g., Aouad et al. 2010). Ozorhon (2013) suggests that innovation processes in construction includes company, project, and industry levels, and emphasises the importance of project-level innovation, to reach common goals. However, Wei and Miraglia (2017) argue that experiences are unlikely to be systematically documented to benefit other projects. Collective learning tends to occur within projects and the acquired knowledge dissipates when new constellations are formed.

The industry lacks agents with roles who can act as owners of the process. Clients have the main control over design and production processes. However, the client lacks both the competence and resources to optimize design and production at an industry level. As noted by Harty (2005), the distribution of power is an important characteristic of construction. Even if the construction work is coordinated by a main contractor, all the participants in a project have their own expectations, discipline-specific tasks, and their own way of work.

2.3 Implications of the nature of the construction industry for DT

An important aspect of the construction industry for DT is that much of the scope, key constraints, and factors that could potentially promote innovative change are organisational-level features, due to the industry's fragmentary nature (Ozorhon, 2013).

On company and project levels, incentives and factors that may promote innovative change frequently include establishment of a creative culture fostered by the need to solve problems that arise (Dubois and Gadde, 2002) and collective learning within its framework (Wei and Miraglia, 2017). Digital solutions and other innovative changes can be implemented if they support common goals, and occur within the framework of existing roles, responsibilities and working methods. However, there is little capacity to transfer learning between projects and from projects to participating companies (Wei and Miraglia, 2017).

On the industry level, due to the lack of a process owner no one has the capacity or authority to drive overall changes (Reichstein et al., 2005). Structural changes are also inhibited by the suboptimization, as each stakeholder lacks incentives to enhance the whole process (Love et al., 1998; Nawi et al., 2014).

3. METHOD

This study is based on a systematic review of literature on DT in the construction industry, limited to the design and production phases. Neither early, municipal-level planning phases nor the facility management phase are included. Planning, Construction and Facilities management are three extensive and different processes in the built environment sector. The focus of this study is Construction; the other two is driven by other business logics and partially other stakeholders. In addition, due to the aim to facilitate DT of the construction industry, encapsulated in RQ 3, the reviewed literature only includes studies that provided practical knowledge and experience based on empirical data, thus excluding previous reviews.

3.1 Data collection

To collect relevant data, the Scopus database was used, which covers a wide range of scientific publications and has a fast-indexing process (Zhao et al., 2019). The keywords applied, exclusion criteria, and numbers of papers retained at each stage in the process of identifying papers to include in the review are shown in Fig. 2. The first step was to identify search terms encompassing the scope of the study. This was defined as the intersection of areas encompassed by two principal terms: "digital transformation" and "construction industry". Therefore, the search string consisted of a combination of the terms in Fig. 2, including several synonyms for both terms. Since the aim is to collect articles that explicitly address "digital transformation", keywords that include broader concepts such as IT, digitalisation or digitisation are not used, nor are keywords that refer to individual technologies such as BIM, VR, digital twins or the like.

The primary search resulted in 82 articles, with a distribution of publication dates shown in Fig. 3. The database was searched in February 2021, which explains the sharp drop in numbers of retrieved papers published in 2021. The search contained no limitation in time backwards, and Fig. 3 indicates that the area started to gain focus in the

late 2010s. Using the automated function in Scopus, articles that were not published in journals or conference proceedings were excluded, resulting in retention of 70 articles. Another 36 articles were excluded following a manual review of all abstracts, and in some cases entire articles. Most of these 36 articles (23) were excluded because they presented reviews, and the other 13 articles were excluded because they were not published in journals or conference proceedings, did not address the construction industry, were not available to access, or not written in English, as shown in Fig. 2.

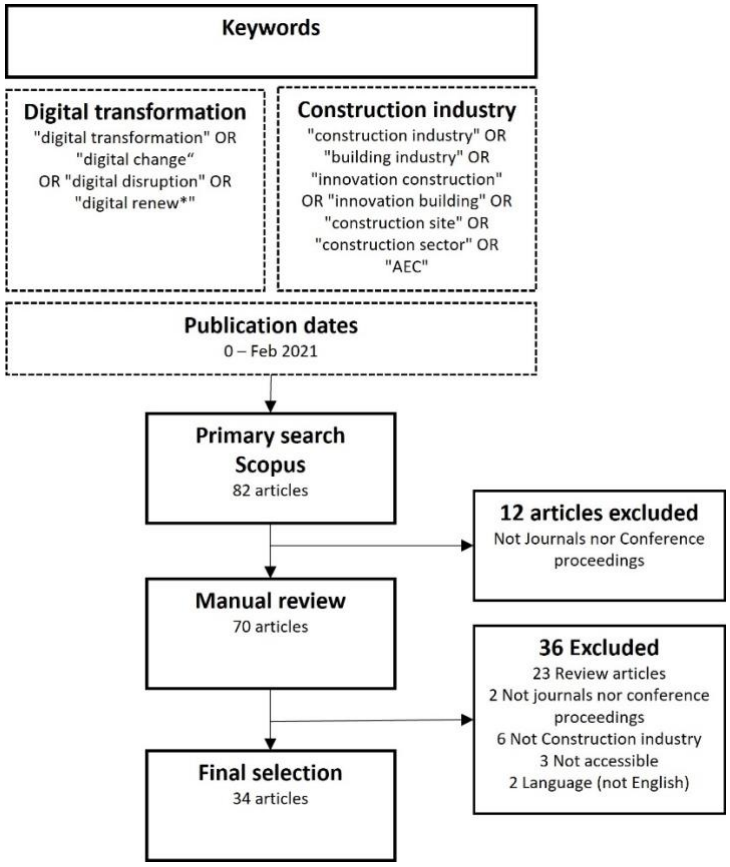


FIG. 2: Number of papers retained at each stage of the data identification process

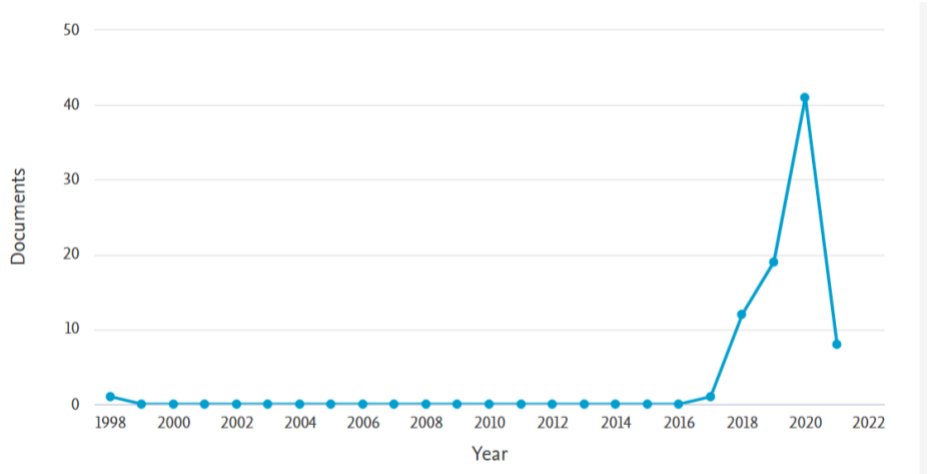


FIG. 3: Numbers of documents, by publication year, retrieved from the Scopus search (Feb 2021)

3.2 Data analysis

The collected data were analysed using the procedures proposed by Vial (2019). Henceforth, we use the term "building blocks" from Vial (ibid) to refer to the eight main parts of the model (Fig. 1). The data analysis involved five main steps with an iterative repetition (step 3) of steps 1 and 2.

Step 1 consisted of defining the headers for each building block (A – I) in a *general description* and some *typical concepts* (Table 1) related to each general description. The general descriptions and typical concepts were initially based on the building blocks presented by Vial (2019).

TABLE 1. Description of building blocks in the analytical model (result of last iteration)

Building blocks	***General description***	***Typical concepts***
A. Use of digital technologies	Use of different digital technologies at individual or organizational level. May include focus on one or more designated technologies in the industry. Does not include processes involved in achieving use, such as implementation or adoption.	• Use, Use cases. • Different technologies (e.g., BIM, IoT, digital twins, visualisation, AI, automation, platforms).
B. Disruptions	External pressures or drivers of change, created (for instance) by clients, end users, regulations, cooperating organizations (other stakeholders in the industry), competitive landscapes (existing competitors or new actors), and technological opportunities (e.g., availability of data, AI, IoT).	• Customer/client demands/expectations, • Competitiveness, • Uncertainties, • External motivation/push/pressure.
C. Strategic response	Strategies or strategic decisions at any level (company, project, industry) influencing or driving changes regarding digitalization in a certain direction with the aim of achieving an organizational-level goal.	• Strategy/Strategic Managers/Managerial/Management, • Foresight, • Significant/long-term changes, • Policy, • National/company guidelines/agreements/platforms.
D. Changes in value creation paths	Changes in ways value is created in an ecosystem, and/or changes in charges for created value, caused, or driven by digitalization.	• Value proposition/network/chain, • Business models/value/process, • Supply/value chain, • Change/transformation in benefit, • Fragmented industry/ecosystem value.
E. Structural changes	Changes in organizational structures at any level (company, project, industry) caused or driven by digitalization. Includes leadership issues and roles of individuals in organizations and their knowledge and skills enabling exploitation of digitalization.	• Organizational change/structure/ frame/culture, • Process/workflow change, • Leadership/Managerial/Management change, • Employee/individual/professionals/users roles/skills/experience/competencies, • Coordination/collaboration/partnering, • Fragmented industry structure.
F. Organizational barriers	Organizational barriers, such as individual or organizational inertia or resistance, hindering DT.	• Reluctance/readiness/barriers to adopt, • Conflict/differences in maturity, • Risk of no positive impacts, • Lack of incentives, • Protective behaviour, • Return to old work methods/processes, • Motivation.
G. Negative impacts	Possible results and effects of digitalization with undesired outcomes.	• Negative outcomes/results/changes, • Overestimation of digitalization, • Worries of digitalization, • Lack of security/privacy.
H. Positive impacts	Possible results and effects of digitalization with desired outcomes.	• Actors' expectations, • Potential, Opportunities, Benefits, • Optimizing, Advantage, • Enhancements (e.g., in terms of quality, sustainability, efficiency, productivity, RoI, safety, security, usability, energy efficiency, costs, times, risks, use of resources, waste, and emissions), • Automation, Communication.
I. Others	Possibly DT-related areas in the articles that could not clearly be linked to any of the eight building blocks of the DT process	

In **step 2** all the selected articles were read, and keywords and sentences related to the general description and typical concepts were noted in a matrix. Each article was read fully to understand its purposes, results and their connection to DT as depicted in Fig. 1. Then, in a second review of the paper, keywords and sentences related to DT were again noted in the matrix, seeking to retain openness to other aspects and factors in the articles that could influence DT but could not be readily assigned to any of the categories (building blocks) in Fig. 1. This resulted in an "other" category that was handled in the same way as other findings in further analysis.

Step 3 was an iterative step in which the *typical concepts* identified in step 2 were extended and refined regarding to the findings in step 2 and resulted in the finalised table 1. Step 2 was then repeated to check the categorization, which resulted in some changes in the categorization.

In **step 4** the categorization in Table 1 was applied to sort the articles in accordance with their content's correspondence to the building blocks (A – I) in the theoretical model, as shown in Table 2.

Step 5 consisted of an analysis in two parts. The first part was a quantitative analysis of the presence in the selected articles of empirical findings regarding each of the DT building blocks shown in Fig. 1. The results, presented in Table 2, provide foundations for the reasoning regarding the consideration of DT in construction literature in relation to the theoretical model in Fig 1. In the second part of the analysis, the findings regarding each building block (A – I) were contrasted with the content in the model and summarized by bullet points (subcategories) for each building block. The findings were clustered in classes, which partly correspond to the subcategories in the model, and partly constitute suggestions for other-subcategories of DT in construction. Results of the analysis, presented in Tables 3 and 4, form the basis of a proposal for a framework for DT in construction.

4. RESULTS AND ANALYSIS

4.1 Results

Results of the review are summarized in Table 2, Findings in the articles closely related to the general descriptions and typical concepts in Table 1 served as indicators of the occurrence (marked with an x) of a building block. Table 2 indicates the presence of empirical findings regarding each building block, but not how frequently the article mentions related concepts.

TABLE 2. Building blocks of the model in Fig. 1 discussed (with empirical findings) in each of the reviewed articles

Publications	**A – Use of digital technology**	**B – Disrup-tions**	**C – Strategic responses**	**D – Changes in value creation paths**	**E – Structural changes**	**F – Organi-sational barriers**	**G – Negative impacts**	**H – Positive impacts**	**I – Others**
Aghimien *et al.* (2020a)			x	x	x	x		x	x
Aghimien *et al.* (2020b)					x	x		x	
Aibinu and Papadonikolaki (2020)	x			x	x			x	x
Azzouz and Papadonikolaki (2020)					x	x			x
Bataev (2019)								x	x
Berlak *et al*. (2021)	x				x			x	x
Çelik (2019)	x		x					x	x
Danjou *et al*. (2020)	x				x	x		x	
Ernsten *et al*. (2021)	x	x		x	x			x	
Greif *et al*. (2020)	x		x	x				x	x
Haghshenas and Österlie (2020)			x		x	x			x
Hodorog *et al*. (2021)					x			x	x
Kifokeris *et al*. (2020)	x				x		x	x	x
Klos and Spieth (2021)	x		x		x	x			x
Kluge *et al*. (2020)			x		x	x	x	x	x
Koseoglu *et al*. (2019)	x		x	x	x			x	x

Publications	A – Use of digital technology	B – Disrup-tions	C – Strategic responses	D – Changes in value creation paths	E – Structural changes	F – Organi-sational barriers	G – Negative impacts	H – Positive impacts	I – Others
Koseoglu and Nurtan-Gunes (2018)	x		x		x			x	x
Lavikka *et al*. (2018)		x	x	x	x	x		x	x
Lazaro-Aleman *et al*. (2020)	x				x	x		x	x
Linderoth *et al*. (2018)		x	x	x	x	x		x	x
Lorenz *et al*. (2020)	x							x	x
Martino *et al*. (2019)					x				x
Morgan (2019)			x		x				x
Nasrazadani *et al*. (2020)	x							x	x
Nölle (2020)	x				x			x	x
Oh *et al*. (2019)	x							x	x
Otte *et a*l. (2020)	x							x	x
Papadonikolaki (2018)	x	x	x		x			x	x
Papadonikolaki *et al*. (2019)			x	x	x			x	x
Phang *et al*. (2020)	x	x	x	x	x			x	x
Prakash and Ambekar (2020)				x	x	x		x	x
Vladimirova *et al*. (2019)	x		x	x	x			x	x
Widyatmoko (2020)	x				x			x	
Zeltser *et al*. (2019)								x	x
Total:	**20**	5	15	11	**26**	11	2	**29**	**30**

The Total row in Table 2 reveals large variations in frequencies of empirical findings of the building blocks. Apart from the category Other (I), Positive impact (H) is addressed in the highest number of the publications, followed by Structural changes (E) and Use of digital technology (A). The interpretation of the frequent occurrence of the Other category was that the employed 5 step method was not self-fulfilling (in the sense of generating results that fit the model) but instead was able to include aspects other than the building blocks of the theoretical model.

4.2 Analysis

Tables 3 and 4 show a summary of the literature analysis, with findings classified within the subcategories (bullet points from Fig. 1).

TABLE 3. Classified findings related to building blocks A – D

A – Use of digital technologies	Classified findings	B – Disruptions	Classified findings	C – Strategic responses	Classified findings	D – Changes in value creation	Classified findings
Social	No empirical findings	***Consumer behaviour & expectations***	*User & client driven* *Government pressure* *New generation of employees*	***Digital business strategy***	Strategies for implementation/ adoption Decision support Industry guidelines/ policies	***Value propositions***	New values in part of the process
Mobile	No empirical findings*	***Competitive landscape***	New entrants Technology offering competitive advantage	***Digital transfor-mation strategy***	Strategic change management	***Value networks***	Transformation of the ecosystem Client-driven value change Partnering
Analytics	BIM	***Availability of data***	No empirical findings			***Digital channels***	No empirical findings
IoT	IoT Digital twins (BIM + IoT)					***Agility & ambidexterity***	No empirical findings

A – Use of digital technologies	Classified findings	B – Disruptions	Classified findings	C – Strategic responses	Classified findings	D – Changes in value creation	Classified findings
Platforms & eco-systems	BIM Digital platforms						
Proposals for addition	Robotisation/ 3D-printing Block chain		Need to change industry's fragmented structure (*barrier*)				

Findings regarding organisational levels, such as individual, company, project, industry, were first classified as *I – Other*, but during the analysis those findings were classified in terms of the building blocks of the model. Findings related to building blocks A-I are described below, in terms of occurrence (Table 2), content, and relation to the subcategories (Tables 3 and 4). In the following passages the subcategories are noted in italics, and the classified findings are noted in italics and with quotation marks.

TABLE 4. Classified findings related to building blocks E - H

E – Structural changes	Classified findings	F – Organis-ational barriers	Classified findings	G – Negative impacts	Classified findings	H – Positive impacts	Classified findings
Organizational structure	Industry-level organizational structure Company-level organizational structure Project-level organizational structure	***Inertia***	Organisational inertia hindering change Industry-level inertia hindering change Individuals´ technology frameworks	***Security & Privacy***	Personal worries	***Operational efficiency***	Efficiency and productivity Automation User experience (individual) Project quality Information management (project) Collaboration benefits (project)
Organizational culture	Organizational culture	***Resistance***	Reluctance/ resistance			***Organisational performance***	Value change benefits
Leadership	Leadership					***Industry an society improve ments***	Climate and Environment Product quality
Employees' roles & skills	Individual competence/skills Organizational competence for change Industry sharing knowledge Support						
Proposals for addition	Work methods and processes		Fragmented structure of the industry: • Partnering barriers • Unclear RoI		nefficiency • Focus on ligitalization *per e*, not the effects		

4.2.1 A – Use of digital technologies

By far the most frequently considered technology in the articles is *BIM*, which is addressed in 14 of the articles. However, BIM is not only a technology but also described in the literature as a method and way of working (Shadram *et al*., 2016). It provides a way for many actors of diverse professions and functions to store and transmit information throughout the whole construction process (ibid.). BIM is therefore linked to three of the subcategories: *Analytics*, *IoT* (including digital twins) and *Platforms & ecosystems*. We found no empirical findings regarding the subcategories *Social* or *Mobile*. Other technologies considered in more than one of the articles are "*Robotization or 3D printing"* and "*Block chain technology"*. It should be emphasized, however, that the purpose of this study is not to map existing digital technologies in construction. For overviews of digital technologies in the sector, recent studies by Meuer *et al*. (2019) and Boton *et al*. (2020) can be consulted.

4.2.2 B – Disruptions

Few articles included in the review address disruptions, and they can be assigned to two of the three subcategories. One of these subcategories, *Consumer behaviour & expectations*, includes direct external pressure from "*clients"* and indirect pressure from their customers, i.e., tenants and users of the built environment in general, who have expectations that the construction industry will use digitalisation to develop both processes and products, like other industries. "*Government pressure"*, is also described as a driving force, exerted both through overall rules and guidelines regarding the society's requirements, and through the public sector as a major client in the construction industry. "*The next generation"* of professionals and their attraction to the industry are also treated as external driving forces.

The *Competitive landscape* encompasses several types of highlighted pressures. "*New entrants"* from other industries or start-ups with potential disruptive solutions or business models challenge incumbents. "*Technology offering competitive advantage"* is also described in the articles as a clear driver of digitalisation. However, no empirical findings were found in the review regarding the subcategory *Availability of data.*

In addition to the three mentioned subcategories, some articles treat the "*Fragmentation in the construction industry"* and needs for changes of the industry's entire structure and logic, as drivers of adaptations that are accelerated by the ongoing digitalisation. Conversely, the industry's fragmentation could be regarded as a barrier that inhibits disruptive changes.

4.2.3 C – Strategic response

Three classes of findings related to the subcategory *Digital business strategy* have been formulated from findings in the reviewed articles. Two of these are "*Strategies for implementation"* of different technologies in companies or projects, and "*Decision support"* in the form of systems or as part of a strategic process. The third, "*Industry guidelines or policies"*, can be considered as common strategies agreed by multiple companies to upscale benefits through collaboration in projects. Findings regarding the second subcategory of strategic responses (*Digital transformation strategy*) are less comprehensive, but some articles address "*Strategic change management"*, focusing not only on improving existing work methods, but also on changing products, services, or processes.

4.2.4 D – Changes in value creation paths

We detected no empirical findings in the reviewed literature regarding two of the four subcategories: *Digital channels*, concerning use of digital technology to change sale channels and distribution, and *Agility & ambidexterity*, which can be summarized as the ability to adapt to changes in environmental conditions. Most of the findings regarding this building block are connected to *Value networks* and have been divided into three classes: "*Transformation of the ecosystem"* (concerning industry-level process and business changes), "*Client-driven value change"* (concerning clients' opportunities to make demands) and "*Partnering"* (concerning the new values that can be obtained through closer, strategic collaboration).

Some findings are connected to *Value propositions*, a subcategory that includes innovative solutions and gathering data, often with increasing numbers of services, to meet customers' needs. The empirical findings reported in the reviewed literature are characterized by changes in specific parts of the construction process or the incentives, value chains or business models of specific actors.

4.2.5 E – Structural changes

Structural changes comprise one of the areas covered most extensively in the reviewed articles, which provide empirical evidence regarding all four subcategories of this building block, but most concern *Organisational structure* and *Employee roles & skills*. The findings regarding *Organisational structure* have been divided into three classes: "*Company"*, *"Project"* and *"Industry"* level (half concern industry-level factors). A large proportion of the articles also address *Employees' roles & skills*, and these findings have been divided into four classes: "*individual competencies & skills"*; "*organisational competence"* for managing change; the ability to "*share & exchange knowledge"* within the industry; and issues regarding "*support"* for the development of competence and skills.

In addition, some of the articles also address another, designated "*Work methods & processes"*, concerning the necessity of adapting new ways of working and not only implement digital technologies and tools in old processes.

4.2.6 F – Organisational barriers

The building block Organisational barriers is divided into the subcategories *Inertia* and *Resistance***.** There are findings regarding both subcategories, showing that they can occur at "*individual"*, "*company"* or organisational, and "*industry"* levels. In addition, "*partnering"* barriers was identified as a distinct subcategory, but with clear links to industry-level inertia, as partnering is one of several ways to change roles and structures in the industry. Another addition found in the articles is a connection between investments needed and return on investment (RoI), which is summarized in the class "*Unclear return of investments*."?

4.2.7 G – Negative impacts

Findings regarding Negative impacts are only reported in two articles. One concerns the single subcategory of *Security & Privacy*. The other concerns the risk of "*Inefficiency"*, i.e., that excessive focus on digitalization *per se* may cause too little focus on the desired effects of digitalization.

4.2.8 H – Positive impacts

More findings concerned Positive impacts than any other building block. The vast majority concerned the subcategory *Operational efficiency*. These findings were sorted into six classes, as shown in Table 3, where the emphasis is on efficiency at the project level. A few statements concern *Organisational performance,* in terms of innovativeness, financial performance, firm growth, reputation, and competitive advantages. Regarding *Industry & society improvements*, two classes of findings were identified: "*Climate & Environmental"* aspects and improved "*Quality of the product"*, i.e., the quality of the final result of the construction project.

4.2.9 I – Other

Thirty of the 34 included publications cover aspects that are not captured by the building blocks A-H. However, they were assigned to just two major classes of findings: *Implementation & adoption* of technology (a distinct, extensive research area, but closely connected to the realisation of DT) and *Development* of digital tools, methods, or platforms.

5. DISCUSSION

The discussion is divided into three parts where we first reason about factors that receive little focus in the construction literature and analyse them in relation to general conditions in the construction sector. In the next part we propose a framework for digital transformation in construction based on Vial´s (2019) model with adjustments to adapt to the construction industry. In the third part, areas for further research that are needed to support the construction industry to benefit from the digital transformation are suggested.

5.1 Factors affecting DT in a construction context

Comparing Vial's conceptual model and its factors influencing DT with corresponding factors from construction literature, the differences are presented under two headings connected to specific conditions found within the construction industry.

The construction industry is 1) *driven by a B2B logic* and 2) *is fragmented and project based*. Findings related to these conditions are discussed in in this chapter as response to RQ1 and will also provide foundations for answering RQ 2 and RQ 3 in sections 5.3 and 5.4.

5.1.1 A business-to-business driven industry

Unlike many other industries, the construction industry has low focus on dialog with consumers and instead has a business logic, based on companies providing services and products to other companies. This is important for at least three building blocks of DT.

- *Disruption – Consumer behaviour & expectations*

  There is little disruptive pressure from consumers on the construction industry according to the review. When disruption is addressed in the reviewed articles, they indicate that both designers and contractors must respond to pressures from "the client" and authorities. Findings assigned to the *User & client driven* class do not concern adaptation to customer requirements in the ordinary sense, but rather an attitude that

the client needs to set explicit requirements in procurements regarding how digital information is to be handled in projects. No evidence of a proactive approach with suppliers offering digital solutions and services, was found in the review. The findings are supported by Reichstein *et al*. (2005), who concluded that the client is perceived as the one with main control over the design and production processes.

- *Changes in value creation paths – Digital channels*

  The absence of findings in the review regarding Digital channels are also partly connected to the B2B logic in the industry. According to Vial (2019), this subcategory includes "changes to distribution and sales channels", with connections to social media as tools for creating dialog with consumers and their needs and habits. It also includes the use of algorithms for improving efficiency in supply chains. In construction, sales channels via social media are not directly applicable, because of the industry´s B2B logic, but digital tools for creating other sale channels, distribution and logistics are highly relevant to the industry, and are not receiving enough attention according to the findings.

- *Use of digital technology – Social and Mobile*

  In the model presented in Fig. 1 "Use of digital technology" is based on the SMACIT acronym (e.g., Sebastian *et al*., 2017), which refers to Social, Mobile, Analytics, Cloud and IoT technologies. Social and Mobile technologies play important roles in DT, in large part due to their ability to collect large amounts of data and preferences from customers, but they have been much less widely adopted in the construction sector according to the review than in many other industries. However, this is not surprising as a key function of the technologies is facilitation of interactions between providers of products or services and customers who are willing to give away personal data to obtain some kind of benefit. The data are then analysed by the providers and used to adjust and personalise the services. In some cases, the data are also resold to other providers. This logic is far removed from the B2B logic in construction.

5.1.2 A fragmented and project-based industry

The large number of companies in the industry that are interconnected in loosely coupled systems and organised in temporary projects, also influence the following four building blocks and subcategories of DT according to the review:

- *Structural changes – Organizational structure* and *Employees' roles & skills*

  Previous authors have stated that innovations, particularly digitalisation-related innovations, are hampered by the organisational structures in the industry (Dubois and Gadde, 2002; Oesterreich and Teuteberg, 2016). Thus, digitalisation requires changes in organisation and the way business is performed in the sector. Findings of the review support this, as the subcategories *Organizational structure* and *Employees' roles & skills* are frequently addressed and needs for change at multiple organizational levels are recognized. The industry´s project-based and fragmented nature restrict possibilities for single organisations to make necessary changes, since they are parts of larger networks, and raise needs for long-term joint efforts by many parties. Similarly, Aouad *et al.* (2010) conclude that changes and innovations tend to remain "hidden" at project level due to the construction industry's fragmentation, and call for attention to multi-level phenomena when discussing change in the industry.

- *Structural changes – Work method & processes*

  Findings assigned to the *Work method & processes* class summarize recurring recognition in the reviewed articles of a need for changes in working methods and internal as well as external processes, beyond the organisational-, leadership- and knowledge-related subcategories described in the model. Similarly, Reichstein *et al*. (2005) highlights the problem of changing common working methods in the project-based industry.

- *Organisational barriers*

  Findings in the review linked to the *Need to change the industry´s fragmented structure* indicate that the structure of the industry hinders change and creates low incentives for disruption. It is difficult for single companies and organisations to change their business in a disruptive way when they depend on many

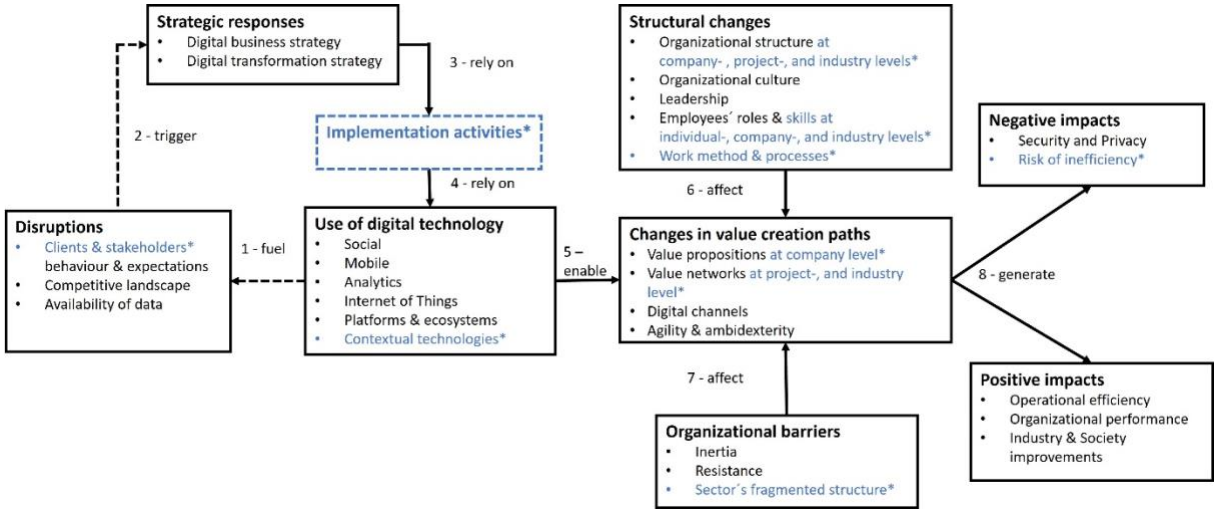
other organisations (Reichstein *et al*., 2005) and well-established processes, procurement models, roles and business models.

- *Changes in value creation paths – Value propositions* and *Value network*

  Findings regarding Changes in value creation path are linked to the two subcategories *Value propositions* and *Value networks*. Findings related to value propositions include a company-level advantage of digitalization; facilitation of efforts by single companies in existing processes to change their offerings. Findings related to value network include calls for network-level changes in value chains regarding roles and business models to create incentives for each stakeholder to contribute to end results of projects rather than focusing solely on optimising own deliveries. Again, the findings show a need for development efforts to include changes at multiple organizational levels.

5.2 Proposal for a DT in construction framework

Based on the findings and discussion in section 5.2, the following framework for DT in construction is proposed in response to RQ 2. The framework is a modified version of Vial's theoretical conceptual model, with additions and adjustments of building blocks or subcategories due to specific conditions in the construction industry.



*) Added or adjusted compared to the model in Fig. 1.

FIG. 4: Proposed Digital Transformation framework for construction, based on the model of Vial (2019), with adjustments

A new block "Implementation activities" is proposed, placed between Strategic response and Use of digital technology. One interpretation of Vial's model is that "implementation activities" are included in "Strategic responses". But since the concept is so frequently mentioned in the studied DT-related articles, there is reason to highlight those activities explicitly. There is also extensive research on adoption (e.g. Venkatesh *et al*., 2003), mainly focused on adoption by individual agents or companies, and both organisation- and industry-level implementation and diffusion (e.g., Succar and Kassem, 2015). This corroborates the conclusion that extensive efforts at multiple levels are required for successful implementation, in addition to formulated strategies and strategic decisions, which is even more important in the project-based construction industry where a single company does not have control over the whole process.

Some articles included in the review focus on development, tests or demonstration of a digital tool or platform, in the context of DT. It can therefore be discussed whether development, test and demo of digital technology also should be included in the framework. However, these perspectives lie beyond the framework's scope as they are phases of development and innovation efforts to create digital technologies to be used, while the framework assumes the existence of digital technologies and describes factors with cause and effect for DT.

Based on the discussion in section 5.2, the subcategory *Consumers' behaviour & expectations* has been changed to *Clients' & stakeholders' behaviour and expectations*. This is because the consumer has low impact on the construction process and disruptive pressure rather comes from the client. However, no building block or subcategory has been removed from the model, even if no (or very few) findings related them were found in the review. It should be noted that the absence of findings regarding a subcategory in the reviewed literature does not necessarily mean that it is not applicable in the construction industry, as it may be due to a shortcoming in either the research or industry.

The building block "Use of digital technology" in the model shown in Fig. 1 is based on the SMACIT acronym. Social and Mobile technologies are recognised as playing key roles in general DT literature, especially through their ability to collect large amounts of data and preferences from consumers. Their current roles in construction are much less prominent than in other sectors but the industry's B2B-logic is not a sufficient reason to exclude them from the framework. Instead, the possibility should be recognized that social and mobile technologies may be used more widely in the context, but probably in different ways than in direct connection with consumers. Other technologies frequently mentioned in the reviewed literature include BIM and automation or robotisation, which calls for addition of a *Contextual technologies'* subcategory. More generally, certain technologies or applications are important for the digital development of every industry and should be considered in DT strategies. To describe and analyse these different contextual technologies for construction is not part of this paper.

The reviewed articles frequently mention different organisational levels when discussing change and DT. Conditions at individual, company, project and industry levels differ substantially, so different kinds of changes at multiple levels are required to create conditions that foster DT. Therefore, these aspects have been added to the building blocks "Structural changes", "Changes in value creation paths" and "Organisational barriers" according to findings in the reviewed articles.

5.3 Further research areas

DT in construction is a relatively new concept that has become widespread in a short time (Fig. 3). However, there was no attempt in any articles included in this review to define the concept of DT. Moreover, few of the articles deal with the transformation *per se*, i.e., technology-driven changes in organisational structures, processes and business models in companies and the industry that constitute DT. Instead, the term is used in the reviewed articles to a large extent as a heading or description of an overall research area rather than directly addressing DT. To reduce the risk of missing articles dealing with the concept of DT without using the exact words, the search terms in the study included both the exact formulation "digital transformation" and the concept it stands for, by using variations of the word "transformation".

Thus, the term Digital Transformation seems to have replaced earlier terms, such as IT, ICT and Digitalization as a description of an area that includes digital solutions for the industry and the changes required to obtain their benefits, but without a common definition of the term or distinction from earlier terms. Understanding of DT in construction can thus be regarded as immature, and there is a need for more research to create a common framework to assist both researchers and practitioners.

Addressing RQ 3 this review highlights a number of key areas within DT where research in construction clearly has gaps to fill. Overall, a clearer common picture is needed of DT in construction, with a scientific approach to the concept and its framework, to obtain a common frame of reference for both researchers and practitioners.

Building on the discussion in sections 5.2 and 5.3, there are needs for further research and empirical evaluation, confirmation, and development related to industry-specific conditions. First, there is a need to explore potential roles in the industry of *Digital channels* and both *Mobile* and *Social* digital technologies. According to the general DT literature they play key roles in strong interactions with consumers. Clearly there are differences in structures, related to the B2B-logic, that hinder such applications in DT of construction, but investigation of how they could potentially be used with adaptation to the conditions of the construction industry is clearly warranted. Second, related to the fragmented and project-based nature of the industry, there is a need for attention to the differing requirements at three *organisational levels* (company, project and industry) to foster DT.

The prevailing conditions seem to preserve roles, processes, value chains and working methods and make it difficult for individual companies to change. At the same time, individual companies (either existing or new

stakeholders) must initiate such change, and research is needed to identify changes in structures, value chains and organisational barriers that those actors should address to break current patterns.

The DT aspects of *Disruption* and *Changes in value creation* call for more attention from scholars. The *Disruption* building block has received little attention, and the reason for this should be investigated further. In particular, more attention is required on ways to access and utilize the abundant data created in the industry processes, which have proven value in other industries´ DT. The building block *Changes in value creation paths* is central to the DT model indicating that such changes are essential for positive effects of DT. Surprisingly, therefore, changes in value creation received relatively little attention in the reviewed articles (only a third of them addressed it at all). Moreover, there were no empirical findings regarding the two subcategories: Digital channels (discussed above), and Agility & ambidexterity. No indications were found that the construction industry would have less reason to focus on Agility & ambidexterity than other industries, rather the opposite. The structures that set the rules for the industry also restrict its capacity for change, which is why a focus is needed on these two subcategories to overcome barriers.

6. CONCLUSIONS

This review of Digital transformation in construction highlights four conclusions:

First, Digital Transformation as a concept is used in the Construction industry since a few years, but with an unclear meaning and content. To be able to use the power of digitalisation in transforming the industry, and not only to make existing processes more efficient, there is need for a common framework for DT that researchers and industry can relate to.

Second, as response to RQ 1 two main conditions in the construction industry affect its ability to drive digital transformation: *The business-to business focus* and *the fragmented and project-based logic*. With the strong focus on B2B, the industry lacks the ability to create direct dialogue with end users and to collect, analyse and use large amounts of data. In other industries, this forms a basis both in value creation and in creating disruptive pressure for change. The fragmented industry with built-in structures that divide stakeholders and their value deliveries into clear stakeholder groups, is an obstacle for individual companies to change. Each stakeholder only contributes with a small part in the value chain, and no stakeholder is clearly responsible for the overall process over time, ie outside the individual project. And vice versa, the lack of companies challenging the structures means a risk that no changes are taking place at the industry level. Developing DT in Construction requires an approach that considers the individual level, the company level, the project level and the industry or network level.

Third, addressing RQ 2 the model from Vial (2019) has been modified according to the characteristics of the construction industry and is proposed as a starting point of a common DT framework for Construction. The general description of DT with its constituent building blocks has proved useful in describing DT also for Construction, but with modifications regarding mainly the strong consumer focus that is assumed into some technologies, and regarding disruptive forces. Implementation and adoption of technologies are identified as an important part of DT in general and are suggested to be highlighted in the DT framework, as an explicit consequence of strategic plans and decisions.

Forth, addressing RQ 3 central aspects of DT, highlighted in the literature, are clearly getting low attention, or are missing in the construction context. The main shortcomings show in the areas of Disruption and Changes in value creation path, which is a worrying result, and should be considered a major obstacle for the transformation of the industry. Low focus on external forces as driver for change, and low focus on changes in delivered value, value chains and business models, risks leading to an erosion of the DT concept, where the remaining parts of the framework do not contribute to transformation at all. It can even be questioned if the area Structural changes, that are getting high attention, will occur if there is no value creation change to address. Thus, deeper investigation of the conditions affecting changes in value creation in the construction industry are required to understand the process and to support companies in the development of value chains, which is the crucial difference between digitalization and digital transformation.

Finally, the clearly increasing research interest in the area according to figure 3, also gives an indication that a follow-up review study in the next few years would be valuable.

This papers contribution to the overall research is threefold. It points out factors in five areas, important for DT according to general literature, which are missing or receive little attention in the construction context: Disruption; Use of digital technology; Structural changes; Organisational barriers; and Changes in value creation paths. The paper also derives reasons for the low attention to two overall conditions within construction: the construction industry's project-based structure and its business-to-business logic. Furthermore, the paper identifies areas in DT in construction which calls for further research in order to achieve benefits of digital transformation.

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