

# Information Management in AEC Projects: A Study of Applied Research Approaches

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**Abstract.** Using the potential that lies within digital transformation seems to be a promising response to reverse the traditional low productivity within the AEC (Architecture, Engineering and Construction) industry. One possible approach to the digital transformation of this industry has been identified as increased and effective use of information in projects. Since only structured information can create value, information management is necessary. This paper provides a systematic overview of the available research on information management in AEC projects with the focus on research approaches. 27 papers were thoroughly analyzed and showed that researchers often give little attention to a detailed description of their research approach. An interpretative/constructivist and pragmatic worldview seems to dominate. The observed research purpose was mainly explorative-descriptive which suggests that information management in AEC projects is a rather young field of research. The most common observed research methods are qualitative and design. Data is mainly collected by case studies and software prototypes are presented as artefacts. Most analyzed papers were conceptual and therefore no data analysis was needed. Whereas the most used method of data analysis for empirical papers was statistical. More empirical evidence through case studies of information management and especially the testing of proposed frameworks and prototypes in real-world projects seems urgent.

**Keywords:** Information management, AEC projects, systematic literature review.

## 1 Introduction

Over the last decades, productivity in the AEC (Architecture, Engineering and Construction) industry has not increased as much as in other industries [1,2]. Using the potential that lies within digital transformation to accomplish faster planned, designed and built projects seems a promising response to reverse this trend. While the AEC industry traditionally is not an early adopter of new trends [3,4], new demands from public clients are pushing the industry towards digital transformation.

One possible approach to the digital transformation of the AEC industry has been identified as increased and effective use of information in projects [2,5]. Software development has made it possible to produce information-rich Building Information

Models (BIM) for both buildings and infrastructure projects [6,7]. Geospatial data contain information about the environment and existing assets. Using geospatial data and Geographic Information Systems (GIS) seems therefore like a promising solution to enhance BIMs even more. Beside graphical information provided in BIM or GIS there is also non-graphical information that is important in AEC projects like e.g. quality assurance documentation. Designers, however, rarely use the available information efficiently since it is unstructured and provided in different silos. Information management is therefore necessary to create value from the available unstructured information.

Since all research should be well grounded in theory and should provide a sound research design [8], this paper aims to provide a systematic overview of the available research on information management in AEC projects. Therefore, the focus of this paper is on the research methodology by addressing the following research questions:

**RQ1:** What is the most common research approach in information management in AEC projects?

RQ1.1: Which philosophical worldviews is the research on information management in AEC projects mainly based on?

RQ1.2: What is the most common research purpose in information management in AEC projects?

**RQ2:** What are the most common research methods in information management in AEC projects?

**RQ3:** What is the most common form of data analysis in information management in AEC projects?

AEC projects can be classified into different phases. In this paper the Norwegian system "Next step" as outlined by Knotten et al. [9] was used. Only papers describing the design and construction phases were included. The author limited the investigation to these phases to focus on the collaboration between design consultants and contractors. According to Fürstenberg and Lædre [10] information management in these phases needs more investigation. Thus, all papers only describing information management in the asset management phase were excluded. Another limitation is on the acronym "AEC" as a search term. While the acronym includes "construction", using it as a search term excludes papers that only use "construction" and not the acronym "AEC" to describe this industry. Including both "AEC" and "construction" would return too many hits and make a qualitative assessment impossible.

## 2 Methodology

A literature review was carried out according to the steps described by Blumberg et al. [11]: 1) build information pool, 2) apply filter to reduce pool size, 3) rough assessment of sources to further reduce pool size, 4) analyze literature in pool and 5) refine filters or stop search.

Firstly, the information pool was built by searching in the following databases: Scopus and Oria – a Norwegian academic library database. Due to limited functionalities,

Oria was only used for double checking the number of hits returned from Scopus. According to Blumberg et al. [11], words that appear in the working title or theoretical concepts presented in the paper are important keywords. Therefore, the databases were searched for both "information management" and "AEC" in all fields using the following expression: ALL("information management" AND aec). This returned around 1,000 hits.

Secondly, filters were applied to only include peer-reviewed journal articles. This was done by ticking off for document type "article". The reviewing process of journal articles secures a high standard of quality at the expense of actuality. Conference papers have either a shorter or non-existing review process. That makes them more actual, but an individual quality assessment of the conferences is necessary. Due to limited resources, such a quality assessment was not possible, and quality was prioritized before actuality. Furthermore, books were excluded because they can consist of assembled publications based on several research approaches and philosophies. This returned 590 articles on Scopus and 526 articles on Oria. Another filter was applied to only include papers that have "information management" in the abstract. This returned 73 articles from Scopus – in Oria this filter was not available.

Thirdly, the titles and abstracts were roughly assessed to check for relevance for this study. Only articles in English describing the design and construction phases were considered. In total 29 articles were found to be relevant for information management in AEC projects.

The steps 4 and 5 involve a full-text assessment of each hits and to either stop the search or refine the filters if the pool is still too large. Since the number of the hits was rather small, no further filters were applied, and the search was stopped. Two papers were regarded irrelevant and excluded after the full-text assessment. Thus, the final sample consisted of 27 unique peer-reviewed journal articles.

Lastly, all the papers of the final sample were analyzed regarding the underlying research approach, research methods and analyses of the collected data. For this purpose, an Excel spreadsheet containing their attributes was created. Title, author name(s) and publication year were exported from a reference handling tool. The following attributes were extracted from the papers: research approach, philosophical worldview, research purpose, research method(s), instrument(s) of data collection and type of data analysis.



**Fig. 1.** filtering process to obtain the final sample

## 3 Theoretical Background

### 3.1 Information Management

Information management is a term used in different fields of research (e.g. business and management, information and communication technology (ICT), or librarianship [12]). Detlor [13] describes information management as "the management of the processes and systems that create, acquire, organize, store, distribute, and use the information". He outlines three major perspectives: organizational, library and personal. From the library perspective, information management concerns the collection of information and providing it to users. From the organizational perspective, information management serves the goal to archive business objectives and strategies. From the personal perspective it serves the goal to archive objectives of the individual. Information management of AEC projects has the organizational perspective.

With the ever-increasing number of data files created in our society, the (unstructured) information increases as well. AEC projects are no exception and produce different forms of information, both graphical (e.g. 3D models, drawings, visualizations) and non-graphical (e.g. technical guidelines, technical reports or QA documentation). While the importance of information management of AEC projects was reported on earlier [14,15] it was the digital transformation that raised its importance even more. For example, it is possible for an experienced user to find relevant information on a drawing even if it is unstructured. Whereas it is difficult to almost impossible to find relevant information in digitally transformed projects where information is only stored in digital models. A systematic management of information is therefore necessary. "Better Information Management" as an alternative description of the acronym BIM or the designated role of an "information manager" in the UK are other indicators for the increased importance of information management in AEC projects. Furthermore, Fischer et al. [16] report that especially new delivery forms within AEC projects, namely Integrated Project Delivery (IPD) could benefit from "integrated information" by information management.

For the author, information management is a managerial task supported by IT systems that aims to improve the workflow within AEC projects. Therefore, the overall goal of information management is to provide the right information at the right time for the right users.

### 3.2 Digital Transformation

Practitioners and researchers use different definitions of the digital transformation process in AEC projects, some of the definitions are frequently used interchangeably. I-scoop [17] distinguishes "digitization", "digitalization" and "digital transformation" .

- **digitization:** "transformation from analog to digital (...) with the goal to digitize and automate processes or workflows".
- **digitalization:** "use of digital technologies and of data (...) in order to create revenue, improve business, replace/transform business processes and create an

environment for digital business, whereby digital information is at the core." In other words, using the digitized data to create an improved product.

- **digital transformation:** builds upon digitization and digitalization and "encompasses all aspects of business, regardless of whether it concerns a digital business or not, ... ultimately leading to a new economy."

### 3.3 Classification of Research Approaches

To set research in a broader context, especially for research within social sciences, it is important to know its theoretical perspective or "philosophical worldview" [8]. This worldview influences the researcher and should therefore always be addressed in advance. Several authors use different classifications. While Neuman [18] describes five types of social sciences – *positivistic, interpretative, critical, feminist, and postmodern*, Creswell and Creswell [8] describe four worldviews – *post-positivism, constructivism, transformative and pragmatism*, Saunders et al. [19] describe four slightly different categories – *positivism, interpretivism, realism, and pragmatism* and Blumberg et al. [11] describe three categories – *positivism, interpretivism and realism*. Based on these different classifications, the author regarded the following three categories most appropriate for the purpose of this paper.

**(Post-)positivism:** Positivists think that all knowledge already exists, and theory needs to be deduced from it. Post-positivists however agree that knowledge is not the absolute truth for studying human behavior [8]. (Post)positivist researchers are objective, believe only in "real facts" [20] and have the explanation of causality as their overall goal. This worldview is rooted in natural sciences and was introduced in the 19th century. Quantitative methods are used for data collection.

**Interpretivism/constructivism:** Constructionists think that knowledge depends on the social context and needs to be created inductively by interpreting observations [21]. Alvesson and Sköldböck [20] describe an "aha experience" as central in many publications. Interpretivist/constructivist researchers are not objective and often they "want to criticize, change, or destroy some X that they dislike in the established order of things" [22]. Creswell and Creswell [8] state that constructivist researchers rely "as much as possible on the participants' view of the situation studied" and that they recognize that their own background influences the interpretation of the observed phenomena. This worldview was introduced in the 1960ies. Qualitative methods are used for data collection.

**Pragmatism:** Pragmatists center their research around the research question [19]. It is also important to build a rationale [8]. Pragmatist researchers can be objective or subjective, but they acknowledge that research occurs in social contexts. This worldview was introduced in 1980ies. Pragmatists use mixed methods for data collection. The use of methods is not strict, they shall serve to understand the problem [23]. Knowledge is created both deductively, inductively and abductively.

The above described worldviews imply different forms of knowledge creation; *deductive, inductive and abductive*. When deducing knowledge, researchers formulate hypotheses based on existing theory. The hypotheses need to be verified or falsified by testing. When inducing knowledge, researchers turn this process upside down. Theory

does not exist yet; it needs to be created inductively by observing real life phenomena. Research questions are used instead of hypotheses. Abduction can be seen as a combination of these two forms. Theory does not exist and needs to be created by observation. Since generalizing from cases may lead to wrong conclusions, the theory needs to be verified deductively by testing at a later stage.

Research can also be approached by the existence of data collection. On the one hand, researchers do collect data and rely on testing before considering ideas as knowledge [24]. In this case they conduct *empirical research*. Normally, empirical studies create knowledge by deduction. However, this depends on the number of the investigated sample. With small samples the knowledge is rather created by induction. On the other hand, researchers do not collect data (or only to a limited extend) and rely on their experience for creating theoretical frameworks. In this case they conduct *conceptual research*. Therefore, conceptual studies create knowledge by induction. However, conceptual research often develops models that are tested empirically at a later stage. In this case, the knowledge is created by abduction.

Yet another research approach is by its purpose, like described by Yin [25]. He uses the following three categories:

- **descriptive:** describes "a phenomenon in its real-world context"
- **exploratory:** identifies research questions or procedures for subsequent studies
- **explanatory:** explains "*how or why some conditions came to be*"

### 3.4 Classification of Research Methods

Creswell and Creswell report on [8] three research methods for empirical studies within social sciences: quantitative, qualitative and mixed methods.

**Quantitative methods:** based on quantitative information which can be collected by surveys or experiments.

**Qualitative methods:** based on qualitative information (text, audio, video) which can be collected through case studies, document analyses, observations or interviews.

**Mixed methods:** a combination of quantitative and qualitative methods.

Vaishnavi and Kuechler [26] report on **design as a research method**, mainly applied for conceptual studies within Information Sciences. Software prototypes or "artefacts" [26] are the result of such studies.

### 3.5 Classification of Data Analysis

Data gathered by quantitative methods consist of numbers and can therefore be analyzed by statistical means. Specialized data programs like SPSS are most commonly used. According to Creswell and Creswell [8] it is important to inform the reader about the types of statistical analyses used.

Blumberg et al. [11] describe content analysis as the most common form of qualitative data analysis. In short, this means coding transcripts, documents, audio and video material. Creswell and Creswell [8] describe this process as making sense out of the collected data by taking them apart and putting them back together.

## 4 Findings

This paper investigated the most commonly applied research approaches, research methods and data analyses in the field of information management in AEC projects.

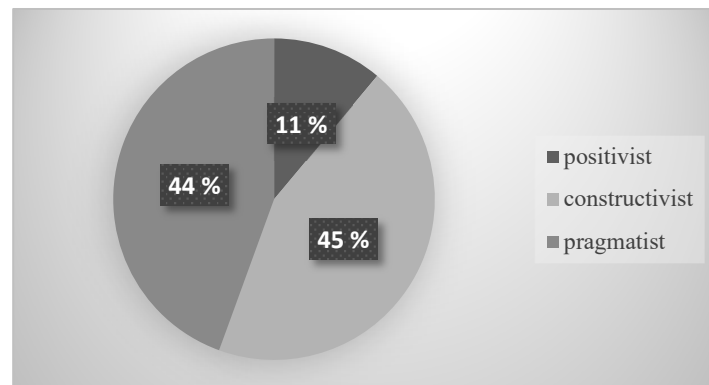
### 4.1 Observed Research Approaches

15 of 27 papers of the final sample do not have a method chapter. Information about the research approach and methods is sometimes only briefly mentioned in the abstract, introduction and/or conclusion chapter. Knowledge is equally created by abduction (11 of 27) and induction (13 of 27), while only three of 27 papers deduce knowledge. Most of the papers investigated are conceptual (19 of 27). 13 of these conceptual papers do not have a method chapter.

**Table 1.** Papers of the final sample.

	Has method chapter	No method chapter	Share
Conceptual	[27], [28], [29], [30], [31], [32]	[33], [34], [35], [36], [37], [38], [39], [40], [41], [42], [43], [44], [45]	70%
Empirical	[46], [47], [48], [49], [50], [51]	[52], [53]	30%
Share	56%	44%	

Only two of the 15 papers that do have a method chapter mention their worldview. One states a constructivist and one both a positivist and an interpretivist worldview which Creswell and Creswell [8] would define as pragmatism. Based on the definitions of the worldviews presented earlier and the research methods used, the remaining papers were classified by the author. Only three papers seem to have a positivist approach (using quantitative methods). Both interpretivist/constructivist and pragmatist worldviews seem to be equally represented in the final sample.



**Fig. 2.** Philosophical worldview

The research purpose like outlined in [25] was mainly exploratory and to a smaller extend descriptive and explanatory (see table 2).

**Table 2.** Research purpose

<b>Purpose</b>	<b>Quantity</b>
Descriptive	7
Exploratory	19
Explanatory	1
<b>Total</b>	<b>27</b>

#### 4.2 Observed Research Methods

Table 3 shows that the majority of the investigated papers used qualitative methods (13 of 27), followed by design as a research method, like outlined in [26]. Quantitative and mixed methods are rarely used but equally shared in the final sample.

**Table 3.** Research methods

<b>Method</b>	<b>Quantity</b>
Quantitative	3
Qualitative	13
Mixed methods	3
Design	8
<b>Total</b>	<b>27</b>

In table 4 the instruments of data collection used in the papers are shown. Although all papers have a literature review, only 12 of 27 papers state that they did such a review to set the research in the context of the existing knowledge. Case studies were mainly used to collect qualitative data. Within the case studies there was an equal share between interviews, observations, document analyses and questionnaires. One paper analyzed typical construction documents like bill of quantities, logfiles or change orders. One paper interviewed engineers from an engineering company about their workflow for data integration. Surveys, logfiles and experiments were equally used to collect quantitative data. In 14 of 19 conceptual papers a software prototype was produced. Four of these prototypes were based on empirical data. 9 of the 14 prototypes were tested under simulated surroundings, none of the prototypes were tested in real projects.

**Table 4.** Instruments of data collection

<b>Method of data collection</b>	<b>Main method</b>	<b>Second method</b>	<b>Third method</b>	<b>Fourth method</b>
Case study (interviews)	1		1	
Case study (observations)	2			
Case study (questionnaire)	1			



<b>Method of data collection</b>	<b>Main method</b>	<b>Second method</b>	<b>Third method</b>	<b>Fourth method</b>
Case study (document analysis)	2			
Literature review	15	12		
Document analysis	1			
Interview	1			
Survey	2			
Logfiles	1			
Experiments	1		1	
Prototype		10	4	
Prototype test (lab)			6	3
<b>Total</b>	<b>27</b>	<b>22</b>	<b>12</b>	<b>3</b>

### 4.3 Observed Data Analysis

Most of the papers investigated (19 of 27) did not explain how they analyzed the data. However, it must be mentioned that 18 of these papers were conceptual. This means only one empirical paper did not describe how the data was analyzed. The other empirical papers analyzed the data either by statistical means or by content analysis like described in [11].

## 5 Discussion

The findings showed that about half of the investigated papers did not have a chapter explaining the research approach, methods or data analyses used. On the one hand, it must be mentioned that most of these papers are conceptual. Conceptual papers usually describe frameworks or develop new methods or prototypes. Strict use of methods is therefore not as important as in empirical papers. On the other hand, like mentioned by Creswell and Creswell [8] all researchers should have a clear standing towards their philosophical worldview before the research is executed as it will influence them. Since only two author groups stated their theoretical perspective only subjective interpretations of the dominating philosophical worldview could be made. It seems like interpretivist/constructivist and pragmatist approaches dominate and these worldviews represent equal shares of the papers of the final sample.

The high number of conceptual papers presenting software prototypes suggest that the main interest of research within information management in AEC projects is on technical aspects rather than processual. Moreover, this high share of conceptual papers indicates that information management in AEC projects lacks a proper theoretical model.

The research purpose of most of the assessed papers is exploratory or descriptive. This suggests that the field of information management in AEC projects is a rather

young field of research. Blumberg et al. [11] explain that exploratory studies work well within fields that are new or little researched.

Qualitative methods are the most common research methods. When design is used as a research method, usually software prototypes are produced and tested under theoretical conditions. The most common instruments of data collection are case studies.

Like mentioned earlier, most of the assessed papers are conceptual ones presenting frameworks, methods or software prototypes. In conceptual studies, data is normally only collected to a limited extend. Therefore, there is limited need for data analyses. Apart from one, all the empirical papers stated how they analyzed their data. Depending on the form of data collection, this was either a statistical analysis or a content analysis.

## 6 Conclusion

This paper set out to find the most common 1) research approach, 2) research methods and 3) form of data analysis in information management in AEC projects. Interestingly, it appears that researchers concentrate on technical aspects rather than processual aspects, despite the importance of the latter. An overweight of conceptual papers indicates that information management in AEC projects represents a novel field of research without empirically based theory. To put it short, a knowledge gap was identified.

Although most authors describe their applied methods to some extent, they are often not clearly marked and thus making it harder for the reader to validate them. Researchers need to pay more attention to properly displaying their methodology. Moreover, this paper revealed that researchers often do not mention their philosophical worldview explicitly. Researchers need to be more aware of their theoretical foundation or more likely, pay more attention to conveying it in the paper.

While different researchers have pointed out the importance of information management in AEC projects, there seems to be little empirical research on how information management is applied in real-world projects. The mainly explorative-descriptive research purpose of the investigated papers suggests that information management in AEC projects is a rather young field of research. Different theoretical frameworks and software prototypes are proposed, but they are rarely tested in real life projects. More empirical evidence through case studies of information management and especially the testing of proposed frameworks and prototypes in real-world projects seems therefore urgent.

Since most assessed papers lacked a thorough description of the research approach the author had to interpret the papers. Therefore, it might be that some of the subjective interpretations are not aligned with the original intentions of the authors of the papers.

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