ARTIGO

EXPLORING POTENTIAL OF AGILE MANAGEMENT IN THE CONSTRUCTION INDUSTRY: A SYSTEMATIC LITERATURE REVIEW

EXPLORANDO O POTENCIAL DA GESTÃO ÁGIL NA INDÚSTRIA DA CONSTRUÇÃO: UMA REVISÃO SISTEMÁTICA DA LITERATURA

EXPLORANDO EL POTENCIAL DE LA GESTIÓN ÁGIL EN LA INDUSTRIA DE LA CONSTRUCCIÓN: UNA REVISIÓN SISTEMÁTICA DE LA LITERATURA

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ABSTRACT:

To carry out more efficient and effective projects, those involved in project management in the construction industry seek alternatives to preserve projects' profit and value, manage change, improve communication with the client, and anticipate risks in the face of unforeseen events. In the face of uncertain and ever-changing scenarios, the Agile methodology has emerged to help the Architecture, Engineering, and Construction (AEC) sector face management challenges. This paper investigates the applicability of Agile methodology in construction project management. Insights from a state-of-the-art were mapped based on a systematic literature review and bibliometric analysis of 26 articles selected using criteria listed in the research protocol. A quantitative analysis of the distribution by year and country of publication and a qualitative analysis of the content were conducted, using codes managed by Atlas.ti software. The characterization of Agile management and the Scrum framework, the problems in construction projects, the application in the AEC industry and the conceptualization of the hybrid approach were analyzed. The authors discussed the main points surrounding the research and validated the benefits Agile adds to construction project management based on the literature.

KEYWORDS: agile methodology; construction projects; project management; Scrum; bibliographic review.

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RESUMO:

Os envolvidos na gestão de projetos na construção civil buscam alternativas para preservar o valor dos empreendimentos, gerenciar mudanças, melhorar a comunicação com o cliente e antecipar riscos diante de imprevistos, a fim de realizar projetos mais eficientes e eficazes. Diante dos cenários incertos e em constante mudança, a metodologia ágil surgiu para ajudar o setor de Arquitetura, Engenharia e Construção (AEC) a enfrentar os desafios da gestão. Este artigo tem como objetivo investigar a aplicabilidade da metodologia ágil na gestão de projetos de construção. Registrou-se o mapeamento de insights do estado da arte com base na revisão sistemática da literatura e análise bibliométrica de 26 artigos selecionados, utilizando critérios elencados no protocolo de pesquisa. Realizou-se uma análise quantitativa da distribuição por ano e por país de publicação e a análise qualitativa do conteúdo, por meio de códigos gerenciados pelo software Atlas.ti. Analisaram-se a caracterização de gestão ágil e do framework Scrum, os problemas nos projetos de construção, a aplicação na indústria de AEC e a conceituação da abordagem híbrida. Os principais pontos que cercam a pesquisa foram discutidos e os benefícios que o ágil agrega ao gerenciamento de projetos de construção foram validados baseados na literatura.

PALAVRAS-CHAVE: metodologia ágil; projetos de construção; gestão de projetos; Scrum; revisão bibliográfica

RESUMEN:

Quienes se dedican a la gestión de proyectos en el sector de la construcción buscan alternativas para preservar el valor de los proyectos, gestionar el cambio, mejorar la comunicación con los clientes y anticiparse a los riesgos ante imprevistos, con el fin de realizar proyectos más eficientes y eficaces. Ante escenarios inciertos y en constante cambio, la metodología ágil ha surgido para ayudar al sector de la Arquitectura, Ingeniería y Construcción (AEC) a afrontar los retos de gestión. El objetivo de este artículo es investigar la aplicabilidad de la metodología ágil en la gestión de proyectos de construcción. El estudio del estado de la cuestión se basó en una revisión sistemática de la literatura y en el análisis bibliométrico de 26 artículos seleccionados según los criterios enumerados en el protocolo de investigación. Se realizó un análisis cuantitativo de la distribución por año y país de publicación y un análisis cualitativo del contenido, utilizando códigos gestionados por el software Atlas.ti. Se analizaron la caracterización de la gestión ágil y el marco Scrum, los problemas en los proyectos de construcción, la aplicación en la industria AEC y la conceptualización del enfoque híbrido. Se debatieron los principales puntos en torno a la investigación y se validaron los beneficios que la gestión ágil aporta a la gestión de proyectos de construcción basándose en la bibliografía.

PALABRAS CLAVE: metodología ágil; proyectos de construcción; gestión de proyectos; Scrum; revisión bibliográfica.

INTRODUCTION

Project management in the domestic and international construction industry is mostly based on the traditional method. This type of management is processed sequentially, with rigidity in the face of changes, causing problems such as increases in costs, delays and rework (Blessie, 2018). In recent years, the adoption of traditional management has been questioned in light of uncertain landscapes that are subject to continual change (Akel et al., 2019). Professionals in the construction sector are seeking alternatives for project management in a way that preserves the profits and value of the projects, while achieving more efficient and effective projects (Durante et at., 2015).

Recent discussions confirm that construction projects have a high degree of uncertainty and risks derived from the complexity of the project due to cultural, political, social and technological issues, which directly affect the construction industry and pose challenges to management. The high number of stakeholders is also an influential factor in the risks of these projects (Silva; Kikuti; Melhado, 2018). The project becomes increasingly complex as frequent changes take place during its life cycle. Any mismanagement of these changes because of poorly defined scopes, ineffective communication with the client and uncertainty over financial issues or third parties compromises its performance and, as a result, compromises the project's success (Arefazar et al., 2019). One of the factors that has had an impact on the complexity of the construction sector was the COVID-19 pandemic. A number of issues emerged, including an increase in raw material costs and a decline in real estate sales. This complex and uncertain environment has meant that the concept of adaptability in the management of these changes and unforeseen events has become even more important for construction projects (Colares; Gouvêa; Costa, 2022).

In the quest to overcome the limitations of the traditional and the nature of uncertainties, the agile methodology represents a way to help the Architecture, Engineering and Construction (AEC) sector confront management challenges (Akel et al., 2019). One assumption is that the agile approach provides flexibility and momentum to project management, responding to changes and issues involving complexity. In addition, it promotes frequent communication between the team and stakeholders throughout the project (Marnada et al., 2022). This methodology originated specifically for software development. In 2001, the Agile Manifesto took place, in which the four values and twelve principles of agile development were declared (Beck et al., 2001). Years later, Owen et al. (2006) raised the question about the applicability of agile into the construction industry and concluded that there is a tremendous amount of potential for contribution and that the benefits provided to software projects would be the same to any other type of project. In recent years, more and more studies have emerged on adopting agile in the construction industry, proving its application and the gains granted to processes and deliveries. however, there is a need to highlight the main applications and contributions of agile raised by these studies in recent years.

This article derives from the master's thesis and intends to investigate the applicability of the agile methodology in the management of Architecture and Construction Engineering (AEC) projects with the mapping of state-of-the-art insights based on a systematic literature review and bibliometric analysis. The article is structured with the description of the methodology, the presentation of bibliometric outcomes and discussions around the topic; and finally, the main conclusions from the research.

RESEARCH METHODS

The methodology used for the development of this research was the Systematic Literature Review (SLR). In this type of review, the entire process of the descriptive study and the criteria adopted are explicitly presented, allowing it to be replicated by other researchers. Some of its advantages include a precise and reliable theoretical structure, which is obtained with greater efficiency and covers a wide range of results and publications (Santos, 2018).

Robson and McCartan (2016) and Santos (2018) listed steps involved in the systematic review process. Based on the aforementioned authors, the following script adopted in this systematic literature review was briefly formulated. The following is a summary of the research protocol with the strategies adopted in Table 1.

Step	Description
Defining the Problem	What are the main agile attributes that apply to construction projects, according to the state of the art, to bring about improvements in management?
Determining the search parameters	Through the adhesion test, the following keywords found were: project management, Agile and construction or buildings.
Choose the scope of the research	Scopus, Science Direct and Web of Science
Delimitation of search criteria	Keywords were combined with the Boolean operator "AND" and quotation marks were used for the compound term "project management". Search for publications from the last 5 years.
Filtering of studies	Scanning titles, abstract and keywords. Selection of articles available to access to the full text on agile methodology and the construction industry obtained from the databases. The exclusion criteria included repeated articles that were not related to the investigated topic.
Data collection and analysis	Reading of full articles and selection of articles relevant to the theme Qualitative data analysis with the categorization of bibliographic research in Atlas.ti software.
Quality assessment	The search sources are secure and the articles considered were peer-reviewed.
Drafting the summary report	Preparing a table with the synthesis of all selected works.

Table 1. Research protocol

Source: The authors (2023).

The first stage of the review takes place by defining the problem, which is characterized as the guiding question of the research previously reported. To determine the search parameters, the keywords from articles published in parallel on project management through agile methodology and the construction industry were first analyzed. After surveying the words most often used to refer to both concepts, an adherence test was performed according to the model presented in the UFPR training (2020), with combinations of the main expressions found. The test began with a search made in the CAPES Periodical Portal to check on the universe of existing publications. Thus, the number of articles located with each combination of key concepts searched in the "General" field was verified, with a period within the last five years and restricted to peer-reviewed articles. The combinations of words that gathered the

most results were “project management”, “Agile” and “construction” and with the terms “project management”, “Agile” and “building”, all found in English in the search fields due to their universality. To complement the adherence test, the quality of the content found in Scopus, Science Direct and Web of Science databases were computed, confirming the prevalence of publications using the three terms mentioned above. Through this search through the databases, a sudden reduction in the number of articles was observed when specific bases were delimited in relation to the universe contained in the CAPES Periodicals Portal, introducing the application of the sample for this systematic literature review.

As introduced in the previous stage, the scope of the search was established with three databases: Scopus, Direct Science and Web of Science. These platforms were chosen because of the presence of a range of academic literature papers, in addition to being eligible and reliable websites. Benachio (2020) and Munaro (2022) opted for these three databases in the initial phase of their literature reviews, attesting to the validity of these referential research means.

The next step was the delimitation of the search criteria. To complement the search with the use of the defined keywords, the resources combined with the Boolean operators "AND" between the three expressions with distinct meanings and "OR" between the similar terms "construction" and "building" were used. Quotation marks are used as a truncation symbol for the compound term “project management”. The search fields to locate the terms were title, abstract and keywords in the Scopus and Science Direct databases. The "topic" field was used in the Web of Science database, which refers to the title, subject and abstract, with the application of the search filter only in the main collection (Core Collection). As for the delimited period, only the publications from the last five years (2018-2022) were considered. Table 2 presents a summary of the search strategy in the databases, with the fields considered and the strings used for advanced search in each database.

Keywords	"project management"; Agile; construction or building	
Database	**Search Fields**	**Search Description (Field: string)**
Scopus	Title, abstract and/or Keywords	Enter query string: **TITLE-ABS-KEY ("project management" AND Agile AND (construction OR building)) AND PUBYEAR AFT 2017**
Science Direct	Title, abstract and/or Keywords	Title, abstract or author-specified keywords: **"project management" AND Agile AND (construction OR building)** Years: **2018-2022**
Web Of Science	Theme (Title, abstract and/or keywords)	Topic: **"project management” AND Agile AND (construction OR building)** Publication Date: **Last 5 years**

Table 2. Database search strategy

Source: The authors (2023).

The preliminary filtering stage took place with a careful reading of the titles, abstracts and keywords of all articles found in the three databases from July 7, 2022 to July 17, 2022. From this first investigation, we selected the articles that correlate the agile methodology with the construction industry with different methodologies and that are adherent to the content studied. The criteria adopted for the exclusion of publications were articles that repeated in the various databases, articles unavailable in full version with access through the institution University Federal of Parana and if any deviation from the investigated theme was found.

With the selected articles, data collection and analysis were then performed. Data was collected by reading the complete texts, mapping the approaches of relations between agile management and civil construction and the main conclusions by the authors. The data analysis will be qualitative, in which the interpretation is made and the understanding of the published contexts is sought. In the table created in the previous step, the main aspects of the methodology, results and conclusions of the studies analyzed were documented. To increase the accuracy of this analysis and ensure the reliability of the results, Atlas.ti software (version 22) will be used. This software helps to organize the review with the management of large volumes of data, whereby coding is done on the proposed theme for the analysis of the content and for extracting reports on the entire sample of research texts. With these codes, a descriptive categorization can be performed. The license used by Atlas.ti belongs to the Science, Information and Technology Research Group at the Universidade Federal do Paraná (Federal University of Paraná).

The articles selected for reading in their full version were inserted into the Atlas.ti software and divided into 5 groups of documents, according to their year of publication (2018, 2019, 2020, 2021 and 2022). The Fig. 1 reveals the Atlas.ti document manager view. In Fig. 2 is the code manager registered in the program, which contains all the codes mentioned in Table 4.

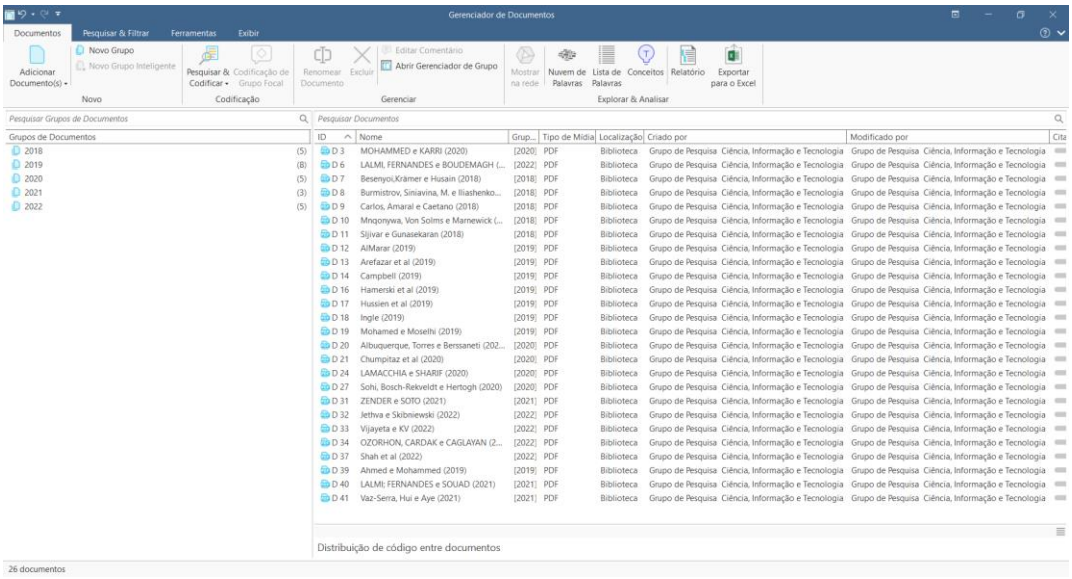

Fig.1. Atlas.ti document manager view

Source: The authors (2023).

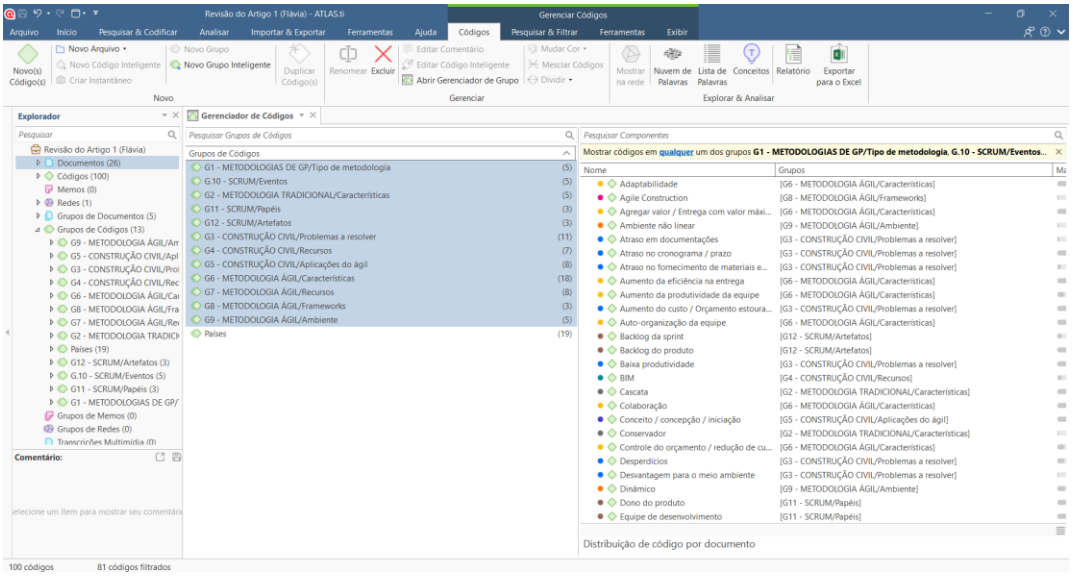

Fig.2. Atlas.ti coding view

Source: The authors (2023).

It can be seen that in Fig. 2 another group of codes appear that do not belong to the previous records, called "Countries". The author used the “codes” feature of the software to facilitate the quantitative survey of distribution by countries of publication. However, the group was not part of the conceptual analysis via coding.

The assessment of the quality of the review is done through the certification of academic research and/or articles published by reliable sources and extracted from reliable databases. Also, the articles were peer reviewed, inferring that the quality of scientific research was verified by specialists.

Finally, a final report was issued with a summary of all the articles selected for the review, the results of which were in line with the initial problem. The information mapped in the data collection stage for each reference was summarized and all the syntheses were grouped in an Excel spreadsheet together with the numbering of the article. This spreadsheet includes a summary of the article, the methodology used and the primary contributions to this research.

According to the sequences listed in the protocol above, it was possible to structure a synthesized diagram with the numbers of publications explored in the filtering process of the studies, using the Visme software, as shown in Fig. 3.

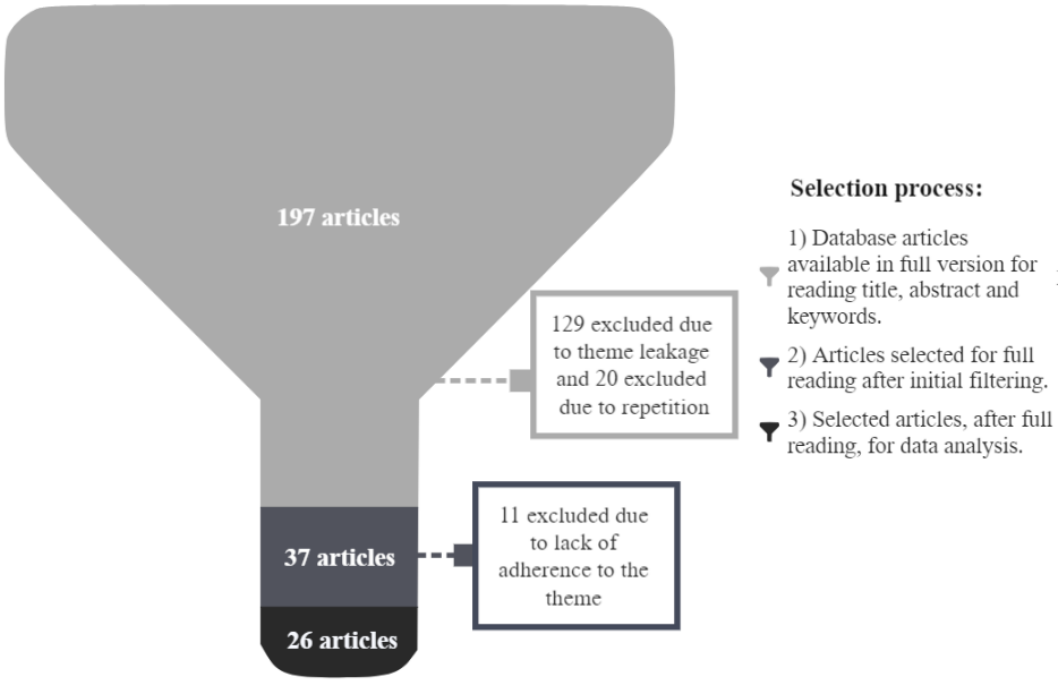

Fig.3. Funnel with number of articles per selection process

Source: The authors (2023).

In processes 1 and 2 of obtaining articles available in full version with access through the institution University Federal of Parana from the databases, for reading the title, abstract and keywords and selecting them for full reading, 186 publications were obtained, 104 from Scopus, 10 from Science Direct and 72 from Web of Science. 69 articles were excluded from those extracted from Scopus, 7 articles from Science Direct and 53 from Web of Science, totaling 129 excluded in the initial reading and, consequently, 57 articles selected for full reading (34 from Scopus, 3 from Science Direct and 19 from Web of Science). It appears that the highest percentage of articles selected for the next stage came out of the Scopus database, making up approximately 61% of publications, while Web of Science and Science Direct correspond to 34% and 5%, respectively. The 57 articles were reduced to 37 due to the repetition of the same articles between the different databases.

In the third process and last process, the articles were selected to follow with this study through the complete reading, verification of points relevant to the theme and contribution to the issue being investigated. Due to lack of adherence to the theme in the development of the research, 11 articles were excluded. At the end of the filtering, a total of 26 articles were collected for data collection and analysis. One observation regarding the selected articles is that four of them refer to the oil and gas industry. However, they were not excluded due to the relevance of the study and the possibility of adding positive discussions to this research.

The content analysis of the articles was based on the approach described by Bardin (1977) of categorizing topics into codes in order to compile the most important contributions of the authors selected in the review and to map the application of agile management in the construction industry. The content analysis developed by Bardin (1977) is divided into the phases of pre-analysis, the development of the material and the processing of the results and interpretations. The pre-analysis phase consists of phases such as a cursory reading of the material, the definition of indices or analysis categories and the preparation of the material for the coding process. In the material exploration phase, the researcher codes the content and assigns the relevant theoretical codes to the categories defined in the preliminary analysis. The

final phase consists of the treatment of the results, the conclusion and the interpretation, in which the coded data are examined, the connections between the categories are analyzed and the relevant meanings in relation to the research objectives are extracted. As for the chosen coding, groups of codes were first created to delimit the points that would be analyzed according to the research theme. The groups are divided into the following categories: project management methodologies, traditional methodology, civil construction, agile methodology and Scrum. In Table 3, there are 5 groups.

Number	Category	Name
G1	Project management methodologies	Type of methodology
G2	Traditional methodology	Characteristics
G3	Construction industry	Problems to resolve
G4	Construction industry	Resources
G5	Construction industry	Applications of agile
G6	Agile methodology	Characteristics
G7	Agile methodology	Resources
G8	Agile methodology	Frameworks
G9	Agile methodology	Environment
G10	Scrum	Events
G11	Scrum	Roles
G12	Scrum	Artifacts

Table 3. Search Code Groups

Source: The authors (2023).

After defining the groups, codes were inserted for each specific group, based on basic concepts in the literature. In addition, as the reading progressed, the codes were complemented with items that were present in the explored articles. The list of all codes used is in Table 4. In all, there are 81 codes created. Codes were included manually in the Atlas.ti tool, and it is clear that they were assigned according to the author's textual and conceptual interpretation.

Group	Code	Description	Number of coded articles
G1	C1	Agile methodology	13
G1	C2	Hybrid methodology (traditional and agile)	4
G1	C3	Hybrid methodology (traditional, agile and lean)	5
G1	C4	Traditional methodology	2
G1	C5	Agile and lean methodologies	17
G2	C6	Cascade	12
G2	C7	Conservative	1
G2	C8	Fixed scope	7
G2	C9	Project Management Body of Knowledge	4
G2	C10	Sequential / linear process	10
G3	C11	Documentation delays	2
G3	C12	Delay in the schedule/time line	15
G3	C13	Delays in the supply of Materials and Equipment	3
G3	C14	Cost increase / budget overrun	14
G3	C15	Low Productivity	8
G3	C16	Waste	6

Table 4. Research codes

Source: The authors (2023).

G3	C17	Disadvantage to the environment	1
G3	C18	Dissatisfied customer	3
G3	C19	Change in the scope of the project (poor	13
G3	C20	Decrease in quality	7
G3	C21	Rework	8
G4	C22	BIM	5
G4	C23	Supply Chain Management of Construction	2
G4	C24	Facilities management	1
G4	C25	Information management	1
G4	C26	Last Planner System of lean	2
G4	C27	Lean construction	1
G4	C28	Augmented reality	1
G5	C29	Concept / conception / initiation	10
G5	C30	Full execution	7
G5	C31	Innovation	3
G5	C32	Operation of the facility	1
G5	C33	Minor changes in the execution	1
G5	C34	Planning	2
G5	C35	Design	10
G5	C36	Restoration / Renovation	1
G6	C37	Adaptability	13
G6	C38	Added value / Delivery with maximum value	13
G6	C39	Increased efficiency in deliveries	13
G6	C40	Increased productivity of the team	6
G6	C41	Team self-organization	13
G6	C42	Collaboration	18
G6	C43	Budget control / Cost reductions	6
G6	C44	Simplicity	7
G6	C45	Flexibility	18
G6	C46	Management of changes	19
G6	C47	Time management / Decreased deadlines	11
G6	C48	Inspection	8
G6	C49	Continued Improvement	13
G6	C50	Improved communication / quick feedback	19
G6	C51	Improvement/sustainable development	5
G6	C52	Effective Risk Resolution / Risk Management	10
G6	C53	Customer Satisfaction	14
G6	C54	Transparency	8
G7	C55	Multidisciplinary team	11
G7	C56	Burndown Chart	1
G7	C57	User history/ Customer Requirements	2
G7	C58	Iteration / Iterative Development	18
G7	C59	Lessons Learned	9
G7	C60	Risk checklist	1
G7	C61	Cyclical process	6
G7	C62	Kanban Board	1

G8	C63	Agile Construction	1
G8	C64	Kanban	2
G8	C65	Scrum	17
G9	C66	Nonlinear environment	1
G9	C67	Dynamic	7
G9	C68	Unpredictable	2
G9	C69	Uncertainties	16
G9	C70	Complex problem	12
G10	C71	Sprint Planning	10
G10	C72	Sprint Retrospective	7
G10	C73	Daily meeting	13
G10	C74	Sprint Review	10
G10	C75	Sprint	13
G11	C76	Product Owner	8
G11	C77	Developers Team	8
G11	C78	Scrum Master	8
G12	C79	Sprint Backlog	4
G12	C80	Product Backlog	10
G12	C81	Increase	12

This chapter details all the steps related to the literature review, the databases and search strategies used, the data collection protocol and the refinement of the number of publications found. In addition, the codes applied in Atlas.ti and the references of the articles selected for the research were also displayed.

RESULTS

This section provides the results of the data extracted from the 26 articles adhering to the theme. Quantitative and qualitative analyses are included. The quantitative analysis will indicate the distribution of publications over the last five years and on the world map. Meanwhile, the qualitative analysis describes the most important agile concepts cited, the most relevant framework, the problems addressed in civil construction that are to be mitigated, the phases of the construction project with agile adoption and information on the hybrid methodology discussed by some authors. Subsequently, pertinent discussions on the results obtained are presented.

QUANTITATIVE ANALYSIS OF SELECTED PUBLICATIONS

The search for articles was followed by a delimitation of periods between 2018 and 2022. Among the 26 studies, the annual distribution of publications is quantified as shown in Fig. 2. The year with the most publications was 2019 and 2021 had the least. However, an upward trend is seen from 2021 to 2022, and given that the survey was conducted at the beginning of the second half of 2022, it is likely that more publications will emerge.

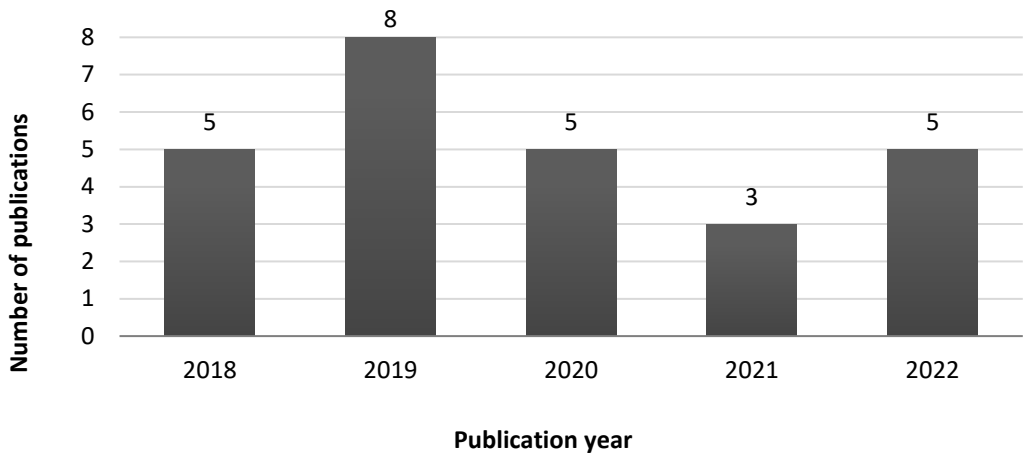

Fig. 2. Distribution of publications by year

Source: The authors (2023).

After surveying the year in which the articles were researched, we proceeded to analyze the location of publication.

The countries where the 26 articles were published were mapped. There was an almost homogeneous distribution in 19 different countries. The countries with the most publications were the United States and India with a magnitude equal to 3 publications. In second place, with 2 publications, were Brazil, Peru and Portugal. The others account for only 1 publication, involving the following countries: South Africa, Germany, Australia, Canada, United Arab Emirates, Netherlands, Iran, Iraq, Ireland, Nepal, United Kingdom, Russia, Saint Vincent and the Grenadines and Turkey. The Fig. 3 shows the distribution of publications on the World Map, through a representation made with the help of the Visme software.

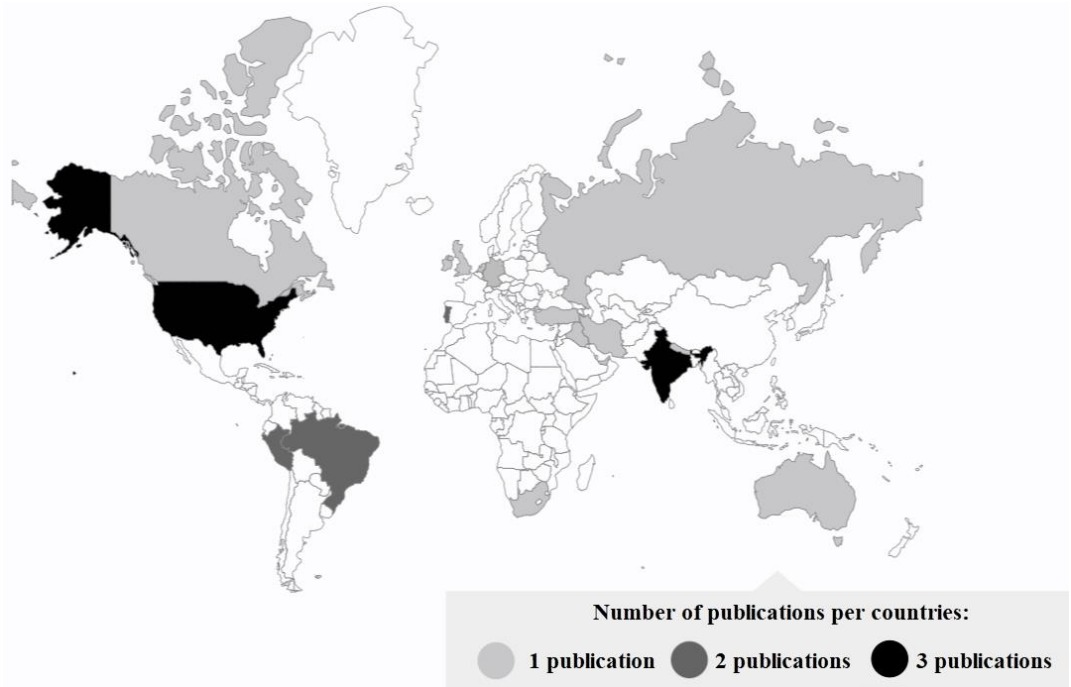

Fig. 3. Distribution of 26 publications on the World Map

Source: The authors (2023).

After the quantitative analysis of articles by year and by country of publication, the content related to the theme of this study was analyzed.

QUALITATIVE ANALYSIS OF AGILE MANAGEMENT FOR THE CONSTRUCTION INDUSTRY

The qualitative analysis of the research was possible through the complete reading of the texts and the coding applied in Atlas.ti. To characterize agile project management, the "Agile Methodology" (G6, G7, G8 and G9) and "Scrum" (G10, G11 and G12) code groups, as documented in Table 4, were analyzed in terms of their magnitude and recurrence of the codes of each set.

CHARACTERISTICS, RESOURCES AND DESCRIPTION OF THE AGILE ENVIRONMENT

A total of 18 characteristics were coded for their appearances in the articles and relevance. Among them, the most cited were: improvement in communication and/or quick feedback; change management; collaboration; flexibility and customer satisfaction. The first two appeared in 19 articles, the intermediate two in 18 articles and the last in 14 articles. With magnitudes equal to 13, meaning that the codes appeared in 13 of the 26 publications, there is: adding value and/or delivery with maximum value; adaptability; increased delivery efficiency; continuous improvement; and self-organization of the team. The least mentioned characteristics were: time management and/or shorter deadlines (11 citations); effective risk resolution and/or risk management (10 citations); transparency (8 citations); inspection (8 citations); easy implementation and/or simplicity (7 citations); and increased team productivity (6 citations).

It was discovered that the four main benefits that agile provides to this sector are: improved communication between project stakeholders; change management through quick responses and a vision of opportunity and competitive advantage in the face of scope changes; the collaboration between the managing team and the customer; and flexibility in the processes, scope and resources used.

Among the resources of agile, iteration was the most cited. Iterative development is directly related to change management because it supports the idea of anticipating the discovery of risks so as not to compromise later deliveries. Burmistrov, Siniavina and Iliashenko (2018), Hussien et al. (2019), Campbell (2019), Mohammed and Karri (2020) and Malla and Prasad (2022) were some of the authors who reinforced the use of iterations in construction projects to mitigate the impacts of changes, as well as to increase complexity through fractions in time. Other agile resources surveyed in the articles with relevant magnitude were: multidisciplinary team, lessons learned and cyclical process. The others referred to like Burndown chart, user stories, risk checklist and Kanban board were not mentioned very much, so they have low usability in construction projects.

The environment for the adoption of the agile methodology was mostly defined as complex and with uncertainties. Siniavina and Iliashenko (2018) and Ozorhon, Cardak and Caglayan (2022) referred to the construction industry with the same adjectives. The dynamic characteristics and unpredictability were also mentioned as attributes of the agile environment and are factors that construction projects constantly portray in daily life.

Table 5 presents a summary of the main characteristics of agile, the most cited resources and the definition of the environment with the respective authors.

Author(s), Year	Characteristics				Resources				Environment			
	Improved communication between project stakeholders	Change management	Collaboration between the managing team and the customer	Flexibility	Iteration	Multidisciplinary team	Lessons learned	Cyclical process	Complex	Uncertainly	Dynamic	Unpredictable
Besenyői; Krämer; Husain, 2018.		●	●		●							
Carlos; Amaral; Caetano, 2018.	●			●	●	●	●	●		●	●	
Burmistrov; Siniavina; Iliashenko, 2018.				●					●	●		
Mnqonywa; Von Solms; Marnewick, 2018.			●	●	●	●		●	●	●		
Sljivar; Gunasekaran, 2018.	●	●	●	●		●			●			●
Hussien et al, 2019.		●	●	●	●			●				
Ingle, 2019.				●	●							
Hamerski et al, 2019.	●		●						●	●		
Arefazar et al., 2019.	●	●	●	●	●			●		●		
Almarar, 2019.	●	●	●		●							
Mohamed; Moselhi, 2019.	●	●	●	●	●	●	●	●		●		
Campbell, 2019.	●				●		●		●			
Ahmed; Mohammed, 2019.	●	●	●	●	●	●			●	●		
Chumpitaz et al., 2020.	●	●		●	●						●	
Albuquerque; Torres; Berssaneti, 2020.	●	●		●	●	●	●		●	●		
Sohi; Bosch-Rekveldt; Hertogh, 2020.	●	●	●	●	●	●	●		●	●	●	
Lamacchia; Chowdhury; Sharif, 2020.		●	●	●	●		●			●		
Mohammed; Karri, 2020.		●			●			●			●	
Zender; Soto, 2021.	●	●	●	●	●	●	●		●	●		
Vaz-Serra; Hu; Aye, 2021.	●	●	●									

Table 5. Main characteristics, resources and description of the agile environment

Source: The authors (2023).

Lalmi; Fernandes; Souad, 2021.	●	●	●	●			●			●	●	●
Ozorhon; Cardak; Caglayan, 2022.	●	●	●	●	●	●	●		●	●	●	
Malla; Prasad, 2022.	●	●		●	●	●			●	●		
Jethva; Mirosław, 2022.	●		●			●						
Shah et al., 2022.	●	●							●	●	●	
Lalmi; Fernandes; Boudemagh, 2022.	●	●	●	●						●		

RELATION WITH VALUES AND PRINCIPLES OF THE AGILE MANIFESTO

Beck et al. (2001) established four values and twelve principles in the Manifesto for agile software development. Based on these, we drafted the Table 6 to correlate each agile principle with the four values and Table 6 that associates the codes used in this research belonging to the groups G6, G7, G10, G11 and G12 with the agile principles. These groups were used because they fall into the "Agile Methodology" category, excluding the groups “Frameworks” and “Environment” because they are not foundations or practices that can be related.

Principles / **Values**	Customer Satisfaction	Competitive advantage of changes	Short term deliveries	Daily work in teams	Motivating the team	Conversing face to face	Functioning as progress	Sustainable Development	Technical Excellence	Simplicity	Team self-organization	Reflection for improvements
Individuals and interactions over processes and tools	●			●	●	●		●		●	●	●
Working software more than comprehensive documentation		●	●		●		●	●	●	●		●
Collaboration with the client more than contract negotiations	●	●	●	●	●	●	●			●	●	●
Responding to changes more than following a plan		●			●			●			●	●

Table 6. Correlation between the 4 values and the 12 principles of the Agile Manifesto

Source: The authors (2023).

After the theoretical correlation between the agile principles and the values established in the Agile Manifesto in 2001, other codes used in this research were surveyed based on each agile principle (Table 7).

Agile principle	Related codes (G6, G7, G10, G11, G12)
Customer Satisfaction	C42, C53, C57
Competitive advantage of changes	C37, C45, C46, C52, C60
Short term deliveries	C39, C40, C47, C58, C75, C79, C80
Daily work in teams	C42, C48, C50, C73
Motivating the team	C42, C50
Conversing face to face	C50, C73
Functioning as progress	C38, C56, C61, C74, C81
Sustainable Development	C51, C56, C61, C81
Technical Excellence	C49, C55, C58
Simplicity	C43, C44, C62
Team self-organization	C40, C71, C76, C77, C78
Reflection for improvements	C41, C54, C59, C72

Table 7. Association of codes with the 12 principles of the Agile Manifesto

Source: The authors (2023).

The analysis of the codes for the "Agile methodology" category and its relation with the Agile Manifesto was conducted in this section and will then be complemented with a further delve into Scrum, the main framework adopted in the studied publications.

SCRUM - MAIN FRAMEWORK ADOPTED

The analyzed articles that presented conceptual structures or agile practices in the construction industry used the Scrum framework as the basis of the approach (Besenyoi; Krämer; Husain, 2018; Sljivar; Gunasekaran, 2018; Almarar, 2019; Hamerski *et al.*, 2019; Ahmed; Mohammed, 2019; Hussien *et al.*, 2019; Ingle, 2019; Mohamed; Moselhi, 2019; Chumpitaz *et al.*, 2020; Lamacchia; Chowdhury; Sharif, 2020; Mohammed; Karri, 2020; Sohi; Bosch-Rekveldt; Hertogh, 2020; Lalmi; Fernandes; Souad, 2021; Vaz-Serra; Hui; Aye, 2021; Zender; Soto, 2021; Jethva; Mirosław, 2022; Ozorhon; Cardak; Caglayan, 2022). Only 2 articles out of the 17 that adopted Scrum in their research mentioned the association with a second framework: Kanban (Mohamed; Moselhi, 2019; Lamacchia; Chowdhury; Sharif; 2020). Agile Construction was addressed only by Campbell (2019). Despite receiving only one mention, Agile Construction is a relevant structure to the theme and suggests a deeper understanding of its strategies for future research.

EVENTS FROM SCRUM

It has been noted that Scrum is a consolidated structure in software development and expands to other areas of complex problems such as those in the construction sector. The main proposed Scrum events in the analyzed works were:

- the Sprint (Besenyoi; Krämer; Husain, 2018; Sljivar; Gunasekaran, 2018; Almarar, 2019; Campbell, 2019; Hussien *et al.*, 2019; Ahmed; Mohammed, 2019; Mohamed; Moselhi, 2019; Mohammed; Karri, 2020; Chumpitaz *et al.*, 2020; Lamacchia; Chowdhury; Sharif, 2020; Sohi; Bosch-Rekveldt; Hertogh, 2020; Zender; Soto, 2021; Jethva; Mirosław, 2022); and,
- the Daily Meeting (Sljivar; Gunasekaran, 2018; Almarar, 2019; Arefazar *et al.*, 2019; Hamerski *et al.*, 2019; Hussien *et al.*, 2019; Mohamed; Moselhi, 2019; Chumpitaz *et al.*, 2020; Lamacchia; Chowdhury; Sharif, 2020; Sohi; Bosch-Rekveldt; Hertogh, 2020; Lalmi; Fernandes; Souad; 2021; Zender; Soto, 2021; Jethva; Mirosław, 2022; Ozorhon; Cardak; Caglayan, 2022).

These ceremonies are related to the advantages of the framework, such as: focusing on communication and continuous feedback meetings, promoting inspection, transparency and adaptation, in addition to managing risks, changes and time with the division of demands into periods of time.

Despite being strongly advocated by the authors, it was observed that, for application in construction projects, some adaptations of practices and processes are necessary. Jethva and Mirosław (2022) stressed the importance of adapting the Scrum team for each phase of the project and emphasizes the difficulty in extinguishing hierarchies in the construction industry. Hamerski et al. (2019) present an idea of using the practice of the Daily Meeting of Scrum adjusting its recurrence. Because some stages of construction projects are slower and to prevent unproductive meetings, Hamerski et al. (2019) proposed a meeting with the same purpose as the daily meetings, instead taking place weekly. They also mentioned the need to answer the three questions of the Daily Meeting: "what was done over the last week? What will be done in the upcoming week? Is there some kind of restriction that will affect what should be done?" (Hamerski et al., 2019).

ROLES OF SCRUM TEAM

The Scrum team's roles are the Scrum Master, the Product Owner and the development team, which are not defined by hierarchies (Besenyoi; Krämer; Husain, 2018; Sljivar; Gunasekaran, 2018; Ingle, 2019; Mohammed; Karri, 2020; Chumpitaz *et al.*, 2020; Lamacchia; Chowdhury; Sharif, 2020; Zender; Soto, 2021; Jethva; Mirosław, 2022).

Some authors have linked scrum roles to integral parts of construction projects. The relationships of architecture, engineering and construction (AEC) industry professionals with Scrum Master, Product Owner and development team will be presented below.

Besenyoi, Krämer and Husain (2018) and Sljivar and Gunasekaran (2018) call Scrum Master (SM) the project coordinator and leader of the development team, responsible for facilitating the project, removing blockages and promoting self-organization. Chumpitaz et al. (2020) and Mohammed and Karri (2020) associated the SM as the person responsible for supervising the project. Chumpitaz et al. (2020) added that the Scrum Master also serves the role of training the development team on Scrum. The facilitator of the construction project in the redevelopment project for the shopping center, for Zender and Soto (2021), was the project manager. Jethva and Mirosław portray the project engineer as an SM whose responsibilities include keeping the team on the fundamentals of Scrum, helping the team with engineering factors from the contractor's perspective, holding meetings, facilitating communication, offering improvements to project management, and seeking solutions to any constraints that pop up.

The Product Owner (PO) was mostly related to the project manager or project engineer (Sljivar; Gunasekaran, 2018; Mohammed; Karri, 2020; Jethva; Mirosław, 2022). Jethva and Mirosław (2022) define the PO as responsible for formulating and prioritizing project scope requirements according to customer needs and stakeholders' expectations. Chumpitaz et al. (2020) and Zender and Soto (2021) understand how Product Owner as a supervisory representative or, according to Zender and Soto (2021), is a role that the Chief Operating Officer assumes by realizing the needs for the progress of project activities and for updating the product and requirements.

The development team was defined by Sljivar and Gunasekaran (2018) as “a multidisciplinary team of engineering and self-managed design providers that negotiates commitments to the Product Owner after each Sprint". (Sljivar; Gunasekara, 2018, p. 3). Chumpitaz et al. (2020) list engineers, architects and supervisors as members of this team. Zender and Soto (2021)

presented a team of five professionals, including a resident engineer, two field engineers and two assistants. Jethva and Mirosław (2022) differentiated the development teams by phases of the project life cycle, and in the project phase, it will be composed of engineers and architects who will develop the project and, in the construction phase, will integrate the members of the contracted company for execution. Besenyői, Krämer and Husain (2018) also underscore the differentiation and openness of the Scrum team as to the addition and/or change of members in the development team according to the life cycle of the project.

ARTIFACTS OF SCRUM

The increment and the Product Backlog were the most pointed out by the authors as Scrum artifacts. Increment or incremental value delivery is intended to monitor and inspect project progress and obtain feedback with each increment to reach success in the final delivery (Besenyoi; Krämer; Husain, 2018; Sljivar; Gunasekaran, 2018; Arefazar *et al.*, 2019; Campbell, 2019; Hussien *et al.*, 2019; Mohamed; Moselhi, 2019; Ahmed; Mohammed, 2019; Chumpitaz *et al.*, 2020; Zender; Soto, 2021; Jethva; Skibniewski, 2022; Ozorhon; Cardak; Caglayan, 2022; Lalmi; Fernandes; Boudemagh, 2022).

The Product Backlog is the list of requirements and required deliverables that will be completed over the course of the project (Besenyoi; Krämer; Husain, 2018; Sljivar; Gunasekaran, 2018; Hussien *et al.*, 2019; Ingle, 2019; Ahmed; Mohammed, 2019; Chumpitaz *et al.*, 2020; Sohi; Bosch-Rekveldt; Hertogh, 2020; Mohammed; Karri, 2020; Zender; Soto, 2021; Jethva; Skibniewski, 2022).

The Sprint Backlog was mentioned by Besenyoi, Krämer and Husain (2018), Ingle (2019), Zender and Soto (2021) and Jethva and Skibniewski (2022) and is conceptualized as a list of tasks that the development team will perform to arrive at the needed increment during the Sprint.

PROBLEMS MITIGATED BY AGILE MANAGEMENT IN THE CONSTRUCTION INDUSTRY

Based on the articles analyzed, the following critical construction problems emerge:

- schedule delays and missed deadlines (Besenyoi; Krämer; Husain, 2018; Burmistrov; Siniavina; Iliashenko, 2018; Mnqonywa, Von Solms; Marnewick, 2018; Sljivar; Gunasekaran, 2018; Almarar, 2019; Arefazar *et al.*, 2019; Hamerski *et al.*, 2019; Hussien *et al.*, 2019; Ingle, 2019; Mohamed; Moselhi, 2019; Chumpitaz *et al.*, 2020; Mohammed; Karri, 2020; Lalmi; Fernandes; Souad, 2021; Jethva; Skibniewski, 2022; Shah *et al.*, 2022);
- the increase in the initially stipulated cost which results in the budget overrun (Besenyoi; Krämer; Husain, 2018; Burmistrov; Siniavina; Iliashenko, 2018; Mnqonywa; Von Solms; Marnewick, 2018; Sljivar; Gunasekaran, 2018; Almarar, 2019; Arefazar *et al.*, 2019; Hamerski *et al.*, 2019; Hussien *et al.*, 2019; Ingle, 2019; Chumpitaz *et al.*, 2020; Lalmi; Fernandes; Souad, 2021; Jethva; Skibniewski, 2022; Shah *et al.*, 2022; Ozorhon; Cardak; Caglayan, 2022);
- poorly managed changes in the project scope (Mnqonywa; Von Solms; Marnewick, 2018; Sljivar; Gunasekaran, 2018; Arefazar *et al.*, 2019; Campbell, 2019; Ingle, 2019; Ahmed; Mohammed, 2019**;** Mohammed; Karri, 2020; Albuquerque, Torres; Berssaneti, 2020; Lamacchia; Chowdhury; Sharif, 2020; Sohi; Bosch-Rekveldt; Hertogh, 2020; Vaz-Serra, Hui; Aye, 2021**;** Lalmi; Fernandes; Souad, 2021; Ozorhon; Cardak; Caglayan, 2022);

- the need for rework (Sljivar; Gunasekaran, 2018; Almarar, 2019; Hussien *et al.*, 2019; Mohamed; Moselhi, 2019; Albuquerque; Torres; Berssaneti, 2020; Chumpitaz *et al.*, 2020; Sohi; Bosch-Rekveldt; Hertogh, 2020; Ozorhon; Cardak; Caglayan, 2022);
- low productivity (Burmistrov; Siniavina; Iliashenko, 2018; Arefazar *et al.*, 2019; Campbell, 2019; Hussien *et al.*, 2019; Mohamed; Moselhi, 2019; Vaz-Serra; Hui; Aye, 2021; Lalmi; Fernandes; Souad, 2021; Ozorhon; Cardak; Caglayan, 2022);
- reduction in quality (Besenyoi; Krämer; Husain, 2018; Sljivar; Gunasekaran, 2018; Arefazar *et al.*, 2019; Hamerski *et al.*, 2019; Mohammed; Karri, 2020; Lalmi; Fernandes; Souad, 2021; Ozorhon; Cardak; Caglayan, 2022); and,
- waste of resources and time (Mnqonywa; Von Solms; Marnewick, 2018; Sljivar; Gunasekaran, 2018; Albuquerque; Torres; Berssaneti, 2020; Lalmi; Fernandes; Souad, 2021; Malla; Prasad, 2022; Lalmi; Fernandes; Boudemagh, 2022).

APPLYING AGILE IN CONSTRUCTION PROJECTS

A number of applications of the agile methodology in a certain phase of the project were indicated by the analyzed publications. The project initiation or design phases (Burmistrov; Siniavina; Iliashenko, 2018; Mnqonywa; Von Solms; Marnewick, 2018; Campbell, 2019; Hamerski *et al.*, 2019; Hussien *et al.*, 2019; Mohamed; Moselhi, 2019; Albuquerque; Torres; Berssaneti, 2020; Sohi; Bosch-Rekveldt; Hertogh, 2020; Lalmi; Fernandes; Souad, 2021; Jethva; Skibniewski, 2022) along with the planning and design phase (Besenyoi; Krämer; Husain, 2018; Burmistrov; Siniavina; Iliashenko, 2018; Sljivar; Gunasekaran, 2018; Campbell, 2019; Hamerski *et al.*, 2019; Hussien *et al.*, 2019; Mohamed; Moselhi, 2019; Mohammed; Karri, 2020; Albuquerque; Torres; Berssaneti, 2020; Jethva; Skibniewski, 2022) were the most mentioned and tend to have a more effective application for the introduction of agile into the traditional construction environment.

Sljivar and Gunasekaran (2018), Campbell (2019), Hamerski et al. (2019), Hussien et al. (2019), Mohamed and Moselhi (2019), Chumpitaz et al., (2020) and Jethva and Skibniewski (2022) certified the adoption of agile in the execution phase of construction projects. In contrast, Mohammed and Karri (2020) validated only for small changes in the execution of the construction.

The use of agile management in innovation projects in the construction industry was touched on by Carlos, Amaral and Caetano (2018), AlMarar (2019) and Lamacchia, Chowdhury and Sharif (2020). Some projects mentioned by Carlos, Amaral and Caetano (2018) in the innovation plan within the company include new products or technologies, market analysis, partnerships and search for resources. Lamacchia, Chowdhury and Sharif (2020) reinforced that agile principles help in the digital transformation of construction projects to improve stakeholder engagement.

Zender and Soto (2021) mentioned the use of agile in a building rehabilitation project, providing an alternative application that would be the renovations. Besenyoi, Krämer and Husain (2018) described the application of the Scrum framework to manage events in Building Information Modeling (BIM), which revealed an applicability of the agile methodology in the operation of the installation after the execution phase is complete.

CONCEPTS ABOUT THE HYBRID APPROACH

The hybrid approach was highlighted in 11 analyzed articles. Hybrid is the combination of practices and principles from different types of methodologies. In the case of the studies in this

review, a combination of agile with other methodologies such as traditional and lean were displayed.

The use of the hybrid methodology between traditional and agile was adopted in research by AlMarar (2019), Mohamed and Moselhi (2019), Lamacchia, Chowdhury and Sharif (2020), Sohi, Bosch-Rekveldt and Hertogh (2020) and Ozorhon, Cardak and Caglayan (2022). The main idea of the authors is to make the transition of the construction sector more flexible, which has predominantly been traditional. Additionally, the benefits of each included practice were extracted.

Lean construction fundamentals were incorporated into agile in some studies in an effort to, mainly, reduce waste in construction projects. Lalmi, Fernandes and Souad (2021) and Lalmi, Fernandes and Boudemagh (2022) combined traditional, agile and lean approaches. Authors Hamerski et al. (2019), Albuquerque, Torres and Berssaneti (2020), Vaz-Serra, Hui e Aye (2021) and Malla and Prasad (2022) introduced practices associated with lean construction with agile project management. The Scrum of agile methodology and the Last Planner System (LPS) of lean construction were incorporated into a new methodology proposed by Vaz-Serra, Hui and Aye (2021), as well as being cited by Hamerski et al. (2019) as a suggestion for a planning and control method.

DISCUSSIONS

Based on the quantitative analysis conducted, a homogeneous distribution was seen in the number of articles over the last 5 years, and there was also a noticeable scarcity of studies around the theme of the present research, due to the reduced number of publications whose portion of the total found in the databases is close to 13%. These data demonstrate that the application of agile in construction is an innovative subject in the academic field and has yet to reach full maturity. Concurrently, since articles from 19 countries were identified in a sample of 26 publications, the internationalization of the topic and the worldwide concern to resolve the management problems in the AEC sector with the agile methodology were confirmed.

Based on the characterization of agile management and construction projects, it was inferred that the characteristics of the agile methodology most recurrent in the analyzed articles are the most needed in construction projects. Major problems in the construction industry, like late deliveries, budget overruns and poor change management, tend to be addressed through agile fundamentals such as change management, effective stakeholder communication, time management, budget control, flexibility and adaptability. Iterative project development helps anticipate risks and more efficiently resolve potential issues. Since the agile environment is similar to the construction environment, which is identified as complex and uncertain, a synergy is created between both so that the agile approach can provide contributions to construction.

To validate the codes used and reinforce the relevance of agile to areas beyond the software industry, the values and principles listed in the Agile Manifesto were associated with the characteristics and practices of the agile methodology and its Scrum framework cited in the articles from the literature review.

Scrum was the main framework surveyed by the authors in the publications, primarily due to the ease of implementation, the iterative approach and the delivery of incremental value through the Sprint and the simplicity of the processes. Some adaptations were proposed for its application in construction projects, but maintained the adoption of the three pillars of Scrum: transparency, inspection and adaptation.

Based on and analysis of the content, an agreement was seen between the authors in the application of agile methodology in the conception, planning and design phases. The project during these stages is considered more subject to changes, uncertainties and more unstable for a shorter period of time in relation to the construction and operation phases. The advantages of agile are well suited to the mitigation of intercurrences during the development of the activities in these stages. In terms of the execution or construction phase, there were still gaps in reaching mature conclusions from the application of agile during the construction phase of a project due to the need for practical monitoring of projects throughout the life cycle. These gaps are related to the high number of construction team members and the extended period for completion. The agile methodology was designed for software development, so it considers reduced teams and short periods because processes happen quickly in the Information Technology (IT) field. Despite being an agile advantage, the literature still does not provide an answer on how to deal with the most time-consuming events of construction.

The challenges faced to implement agile were mainly related to the construction sector's reluctance to abandon the traditional and its lack of understanding on the subject. The transition from traditional to agile has to be done gradually by fostering gains that will be incorporated into the management for the team and providing training to master the methodology and framework. One suggestion would be to first incorporate the agile framework into an innovation project within the construction company so that employees become familiar with agile practices and witness the success of its operation. In fact, adoption in the area of innovation was cited as an application in the construction industry where agile provides improved communication and faster results. Another considerable option raised by some authors was to employ a hybrid approach of methodologies that combines, for example, the advantages of agile and traditional practices. Employing a hybrid methodology would help to reduce the impact caused by the abrupt transition in management and add the benefits of each method to project management. The association of agile and lean was also cited. But, future studies are recommended to deepen the time because the focus of this research was limited to the theme around the agile methodology.

The results obtained with the respective analyzes were presented in this item 3 aiming to answer the problem of the present research. Subsequently, discussions were raised about the applications of agile methodology in civil construction, as well as the most important characteristics in the publications included in study and the cited attention points. The conclusions from the research are outlined next.

CONCLUSIONS

Research on the applicability of the agile methodology in Architecture and Construction Engineering (AEC) project management based on an systematic literature review was conducted in three reliable databases and 26 articles were selected for bibliometric analysis. The state of the art on the application of agile methodology in the AEC sector was mapped based on the quantitative and qualitative analysis of the studies. The results were broken down according to the coding used in Atlas.ti.

The key characteristics of agile project management mentioned by the authors lead to the conclusion that the main attributes of agile for construction projects are effective communication, change management, collaboration and flexibility. These four benefits embody the values listed in the Agile Manifesto and reaffirm the expansion of these fundamentals to the construction industry. Another attribute is the iterative and incremental project proposed by agile, which is a competitive advantage for helping change management and boosting customer involvement and satisfaction.

Scrum turned out to be the most recommended framework. It was established that it is quite feasible to bring Scrum events, roles and artifacts to AEC projects. All are applicable to the processes of the construction sector and allow adaptations in practices according to the specifics in each project.

It was concluded that the primary problems of the construction industry tend to be solved by incorporating agile project management, through successful applications studied by review articles. The authors adopted agile practices in the design, planning, design, execution, operation and plans in innovation phases. However, there is still a need for greater depth in relation to the subject, especially with regard to practical applications throughout the life cycle from the same project. Given that the use of agile is still an innovative step in the construction sector, there is no defined roadmap for the best way to apply it. But the authors reinforced the importance of teaching the methodology to stakeholders involved in the project and emphasizing the purpose of its adoption. A further relevant point was the integration of agile techniques through an agile approach, which involves combining them with traditional and/or lean principles. The hybrid methodology is another factor that seems to have great potential for future research, considering that agile is uncommon in the current environment of the construction industry.

This research corroborates the value of agile attributes in the face of frequent intercurrences not resolved by the traditional methodology. As mentioned in this article, there are still gaps and future studies to compliment conflicting practices and concepts between the software and construction industries. However, it became clear that the foundations of the agile methodology fit satisfactorily in deficiencies in the management of construction projects, such as the rigidity of processes, unmapped risks and inadequate responses to unpredictability. This study also presented the state of the art in relation to the application of agile methodology in the management of construction projects and contributes to the dissemination of agile advantages for the AEC sector.

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