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Review

A Mixed Review of Cash Flow Modeling: Potential of Blockchain for Modular Construction

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Abstract: Cash is considered the most critical resource in construction projects. However, many contractors fail to obtain adequate liquidity due to a lack of proper cash flow management. Therefore, numerous research studies have been conducted to address cash flow-related issues in the construction industry. However, the literature still lacks a comprehensive review of cash flow management, methods and topics, in the construction industry. This study contributes by providing a holistic, up-to-date, and thorough review of 172 journal articles on construction cash flow. To achieve this primary objective, the study applies a mixed review methodology using scientometric and systematic reviews. The scientometric analysis provides the most contributing scholars, the timeline of cash flow research attention, and keywords clustering. On the other hand, the systematic analysis categorizes the cash flow themes, identifies current literature gaps, and highlights future research areas in the cash flow domain. The results show that cash flow analysis gained more research attention in the last two decades, cash flow-based schedule is the most frequent topic in the literature, and optimization techniques are predominant in the literature. Consequently, the study highlights five potential research frontiers. Further, an automated payment framework for modular construction projects using Blockchain-based smart contracts is developed to address some of the literature limitations. This study provides a guideline for future research efforts and raises researchers' awareness of the latest trends and methods of construction cash flow analysis.

Keywords: cash flow; blockchain; smart contract; modular construction; scientometric review; systematic review

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Citation: Assaf, M.; Hussein, M.; Alsulami, B.T.; Zayed, T. A Mixed Review of Cash Flow Modeling: Potential of Blockchain for Modular Construction. *Buildings* **2022**, *12*, 2054. https://doi.org/10.3390/buildings12122054

Academic Editors: Shoeb. A. Memon, Steve Rowlinson, Bonaventura H. W. Hadikusumo and Llewellyn Tang

Received: 14 October 2022
Accepted: 17 November 2022
Published: 23 November 2022

1. Introduction

For many years, construction projects have been known for their high risks and uncertainties [1,2], leading to higher bankruptcy rates in the construction industry compared with other industries [3]. One of the major determinants of the efficiency of the construction industry is the firm's ability to adopt reliable practices in the management of financial resources [4,5]. For instance, Russell [6] stated that about 60% of contractors' failures are related to financial obstacles. However, the financial success of a construction firm does not rely on the amount of the firm's capital [7]. Instead, the firm should manage its cash availability to guarantee to meet all future financial transactions. Therefore, the term "cash flow" is the key performance measure of a project's financial health [8]. Cash flow comprises all the cash expenditures (cash outflow) and all the cash revenues (cash inflow) for a project [9]. Thus, cash flow forecasting indicates the distribution of cash incomes and expenses over the overall project's life cycle. According to Ramli and Yekini [10], accurate cash flow forecasting is essential for a contracting organization to maintain needed working capital for a project to ensure financial viability in the different project stages.

The increasing number of studies on construction cash flow and financial health has encouraged some researchers to conduct literature reviews related to the topic. Therefore, a preliminary search has been carried out to discover these review studies to ensure the novelty of the current study. For instance, Shan, et al. [11] reviewed the construction financing practices in four developed countries, namely the United Kingdom, the United States, Singapore, and Australia. Also, Vigneault, et al. [12] developed a systematic review of the current uses of Building Information Modeling (BIM) solutions for construction cost management. Gundes, et al. [4] conducted a bibliometric analysis, which is a method of mapping the literature, of 259 articles focusing on construction project finance issues. Another bibliometric analysis was conducted by Durdyev [13] to review the causes of construction financial distress, highlighting the leading journals, countries, and authors that contributed to this area. Bhadeshiya and Pitroda [14] reviewed the factors affecting construction financing, illustrating weak cash flow control as a primary factor. Afzal, et al. [15] reviewed articles from 2008 to 2018 concerning Artificial Intelligence (AI) methods used in cost assessment of the construction industry. Ismail, et al. [16] carried out a systematic review of 152 articles to illustrate cost overrun issues in construction projects.

The mentioned review studies on construction financial health lack the following aspects: (1) hardly any review study has been conducted to address cash flow as the main topic. Instead, the majority of the review papers have focused on construction financial attributes generally, including cost estimation, cost control, and construction projects financing, with little attention to the cash flow issues and how researchers have addressed them; (2) quantitative approaches, such as scientometric analysis, have not been exploited on cash flow analysis. The scientometric analysis contributes by measuring the contributions of authors and countries, as well as analyzing research trends and patterns quantitatively, hence minimizing the subjectivity characterized by the bibliometric analysis [17]. (3) previous review articles lack analysis of methods used to assess financial attributes of construction projects, except for Vigneault, et al. [12] and Afzal, et al. [15], who reviewed BIM and AI methods, respectively.

In light of these limitations, scholars interested in construction cash flow and construction practitioners still need a reference guide that assists them in understanding various construction cash flow issues and their solution methods. Many questions are yet to be answered: what are the key topics addressed in the cash flow area and their relationships? Who are the most contributed scholars in this field of study? What is the possible classification of the identified cash flow research topics? What are the methods used in addressing each of the identified cash flow problems? Are there any research gaps in each of the identified categories? And What is the potential of new technologies, e.g., blockchain, in addressing some of these gaps?

Therefore, this study aims to address these research questions by providing a comprehensive, holistic, and up-to-date critical review of 172 journal articles through a mixed review technique. The mixed review methodology adopted in this study exploits the values of the scientometric and systematic review methods. Firstly, the scientometric analysis is employed to address the following objectives: (1) identify the most contributed authors in cash flow analysis research; (2) classify the most frequent keywords in the cash flow domain into clusters and visualize the networks between these different clusters. On the other hand, the systematic analysis is conducted to address the following objectives: (1) identify the ongoing trends of construction cash flow analysis; (2) summarize and classify the methods used to address the construction cash flow issues; (3) identify the gaps in the existing literature; (4) propose future research directions in cash flow research. Further, based on the identified gaps, the study also aims to develop a conceptual framework to tackle cash flow issues using the recent advances in blockchain technology and smart contracts. The proposed framework is applied to overcome the deficiencies in the current payment mechanisms in modular construction projects characterized by challenging financing issues and complex supply chains.

2. Research Methodology

Figure 1 shows the research methodology adopted to achieve the study objectives. Generally, this methodology includes both quantitative and qualitative methods. Bibliometric and scientometric review approaches represent the quantitative method of this study. On the other hand, the systematic review approach is selected as a qualitative method. This mixed review methodology was adopted by many researchers to provide an in-depth analysis of the literature and determine research trends and future directions [18,19]. Further, combining both approaches could mitigate biased conclusions and personal interpretation, as well as provide a detailed understanding of the research domain and its trends [20]. Hence, in this research, the mixed review methodology is adopted to reach the research goal.

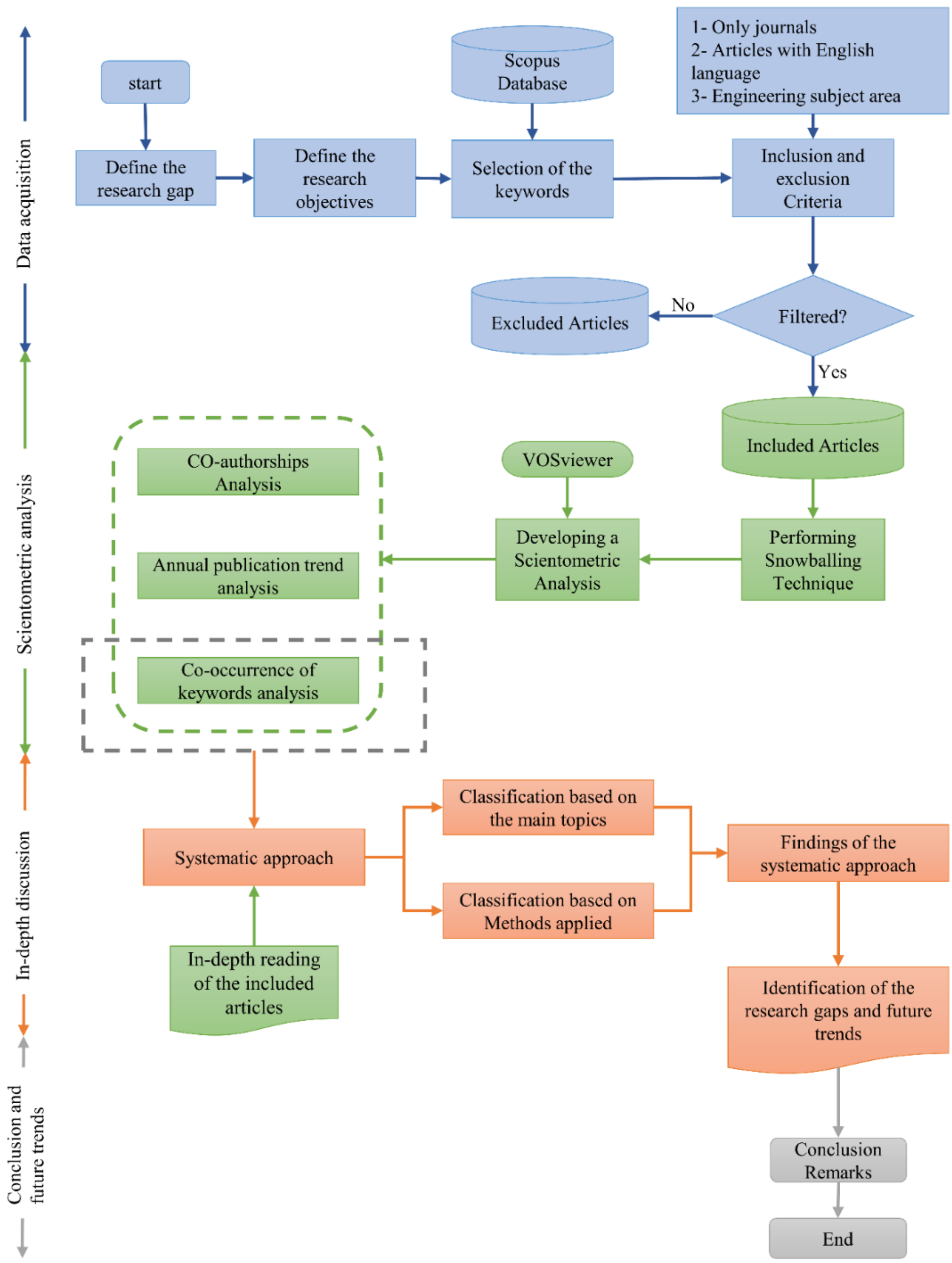

Figure 1. An outline of the research methodology.

2.1. Extraction and Collection of the Relevant Data

The initial stage of the research methodology is to extract the relevant studies of cash flow analysis. Therefore, in this section, the keywords used, as well as the search databases used to search for relevant studies, are selected. Also, this section provides the inclusion and exclusion criteria used to determine the relevant studies. At last, the retrieved studies from the previous steps will be evaluated and screened using a standard review protocol.

2.1.1. Selection of Database and Keywords

A preliminary search was carried out in Google Scholar using the terms cash flow and construction projects to settle on a representative set of keywords required for the comprehensive database search. The obtained studies help select the following keywords: Cash flow, Cash flows, Cash inflow, Cash outflow, Overdraft, Cash deficit, Financial Management, Construction, Buildings, and modular. These keywords represent the common, interchangeable, and representative keywords used in the construction-cash flow research field. Hence, they are used in the database search.

Numerous research databases can be used to extract the related publications, such as Google Scholar, Scopus, and Web of Science. This study analyzes the articles extracted from Scopus due to its broader coverage of the research publications [21,22]. Further, Scopus database is relatively faster in storing updated and recent articles [23]. Hence, the following formula of keywords *(TITLE-ABS-KEY ("cash flow" OR "cash flows" OR "cash inflow" OR "cash outflow" OR "Overdraft" OR "Cash deficit") AND TITLE-ABS-KEY ("construction" OR "building" OR "buildings" OR "modular"))* is used in the Scopus database search. Consequently, 1575 documents are obtained. These documents are assessed according to the identified inclusion and exclusion criteria, as discussed in the next section.

2.1.2. Inclusion and Exclusion Criteria

After obtaining documents from the database search, they are evaluated to exclude the unrelated documents to the study topic based on the identified inclusion and exclusion criteria. The inclusion criteria are (1) journal articles, (2) articles related to the Engineering subject area, and (3) articles written in the English language. By October 2022, applying these criteria results in identifying 366 articles related to the construction cash flow.

2.1.3. Screening and Evaluation of the Included Studies

Following these criteria, the identified 366 articles undergo the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) technique, as shown in Figure 2. The PRISMA technique was introduced by Moher, et al. [24] as a tool for screening and assessing the included articles from the selected database. The first step of the PRISMA technique is to screen the abstracts of the included articles to exclude the irrelevant articles. This process has resulted in excluding 216 out of 366 articles. Then, a full-text evaluation of the 146 articles (366 − 216 = 150) is conducted to ensure that these articles are exclusively related to the study topic. This evaluation has excluded nine out of 150 articles. Next, the backward and forward snowballing techniques were conducted to search for other related studies that might have been missed during the database search [25]. The backward snowballing checks the references of the included articles to find related articles, while the forward snowballing searches for related studies among the articles that cited the included ones [25]. This process is cyclic and has been continued until no new articles are discovered. The snowballing approach has resulted in identifying additional 31 articles to the previously identified ones, increasing the total number of included articles to 172.

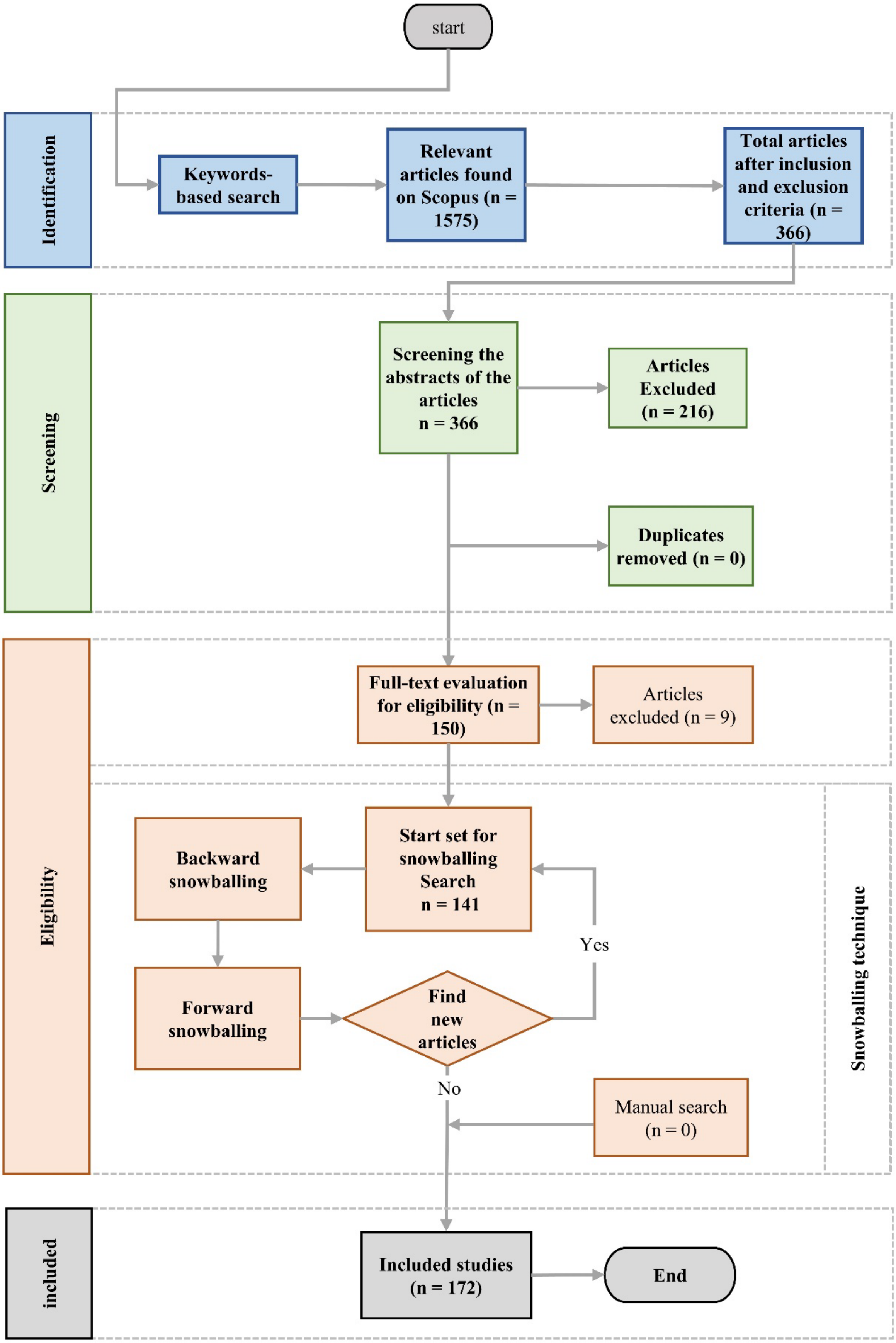

Figure 2. PRISMA technique of screening and selecting publications.

2.2. Mixed Review Methodology

As mentioned above, a mixed literature review is adopted to quantitatively and qualitatively review the included articles. This section provides an explanation of both approaches included in the mixed review.

2.2.1. Scientometric Review

Toward the study objective of quantitively examining the included cash flow articles, the scientometric approach is adopted. The scientometric approach is defined as a quantitative science mapping approach [26]. Science mapping, which is the visualizing of bibliometric data, has become a fitting tool used by many scholars for analyzing and visualizing vast amounts of bibliometric data for a variety of uses [27]. The science mapping technique can typically follow the bibliometric or scientometric analysis. Unlike the bibliometric analysis, which spotlights the literature per se, the scientometric analysis provides a wider approach. The scientometric analysis broadens the values of the bibliometric analysis to comprise the measurement of the scholars', countries', and institutions' contributions in a research domain, as well as recognizing its trends and patterns [28]. Further, the scientometric analysis adopts text mining techniques, which can address the subjectivity associated with systematic reviews [29]. The subjectivity of the systematic review is generally presented in the researchers' own perceptions in analyzing the included data. Hence, the merits provided by the scientometric analysis attracted researchers to adopt this technique in different research topics, including crane planning in offsite construction [30], artificial intelligence roles in construction management [18], and bioclimatic architecture potentials in energy-saving [17].

After obtaining the bibliometric data that meet the inclusion and exclusion criteria, the initial stage of conducting a scientometric analysis is to select the science mapping tool. Several software tools have been established to scientifically map the retrieved articles, such as VOSviewer, Gephi, and CiteSpace [31]. VOSviewer software is selected in this study to map the scientific research of cash flow. VOSviewer is an open-source software tool that develops scientific maps and creates connections between different bibliometric indicators, such as frequencies of keywords, most cited publications, institutions, countries, and so forth. Therefore, the 168 articles obtained from the data extraction processes are identified to VOSviewer.

2.2.2. Systematic Review

Despite the capabilities of the scientometric analysis, it lacks to provide a deeper understanding of the included articles. Conversely, the systematic analysis serves as an additional base for discovering the main existing research directions, highlighting research gaps, and recommending future research directions [17]. Therefore, this approach was adopted by many researchers in the construction domain, such as [32] in the applications of foam 3D printing for construction and [33] in implementing augmented reality in digital fabrication projects.

Having obtained the 172 relevant studies in cash flow analysis, a two-dimensional classification is conducted in the systematic review. The chosen classification is based on the full-text reading and research clusters obtained from the keyword co-occurrence analysis of the scientometric approach. The first dimension of this classification addresses the main topics and themes that were covered by the previous studies. The second dimension represents the main methods and techniques used to address the different areas of cash flow analysis. According to the two-dimensional classification of the included 172 articles, research gaps in cash flow analysis are identified, and possible future directions are established.

3. Results and Discussion of the Scientometric Review of Cash Flow

This section discusses the results of the scientometric analysis that comprises the following: annual publications trends, researchers' contributions in cash flow analysis, and keywords analysis.

3.1. The Annual Number of Publications in Cash Flow Analysis

Figure 3 shows the number of articles on the construction cash flow analysis published annually. In addition, a 3rd-degree polynomial trend line is added to visualize the ongoing interest in this research area over the years. It is noticeable that cash flow analysis did not get enough attention from the researchers in the first decade of the included years, i.e., between 1991 and 2000, except for the year 1996. A potential reason for this phenomenon is that the advancement in computation methods and automated tools that happened in the last decades was missing in this period, obstructing researchers from analyzing the complexity and uncertainties associated with cash flow [34]. However, in the second decade (i.e., from 2001 to 2010), cash flow practices attracted more attention, and the number of publications increased rapidly. In this decade, the researchers' high contributions can be explained by the number of failures that contractors experienced due to financial mismanagement in construction projects [35].

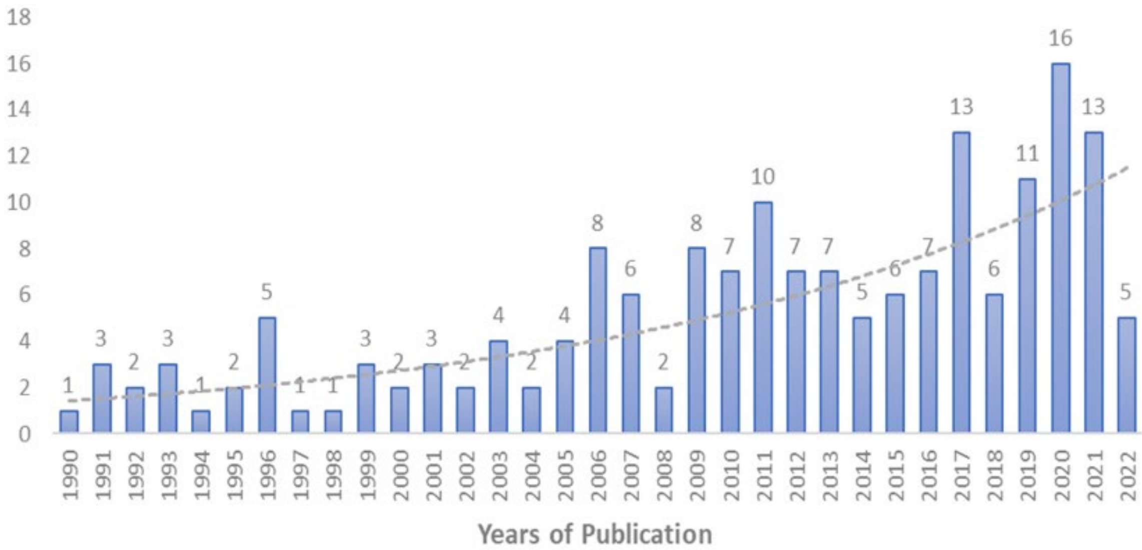

Figure 3. Annual publications of cash flow analysis.

Also, Figure 3 shows that the increase of publications was at a steady rate in the last decade (i.e., from 2011 to 2020). The peak of the publications number is found in 2020 with 16 articles. These observations indicate that construction cash flow analysis would attract more attention from researchers in the near future to address its issues and challenges and enhance the profitability of the construction industry, especially after the negative financial impacts of the pandemic.

3.2. Analysis of Co-Authorships

In this section, the co-authorship networks are analyzed and discussed. These networks visualize and discern the active authors and countries that made the highest contributions in the construction cash flow domain. The significance of the co-authorship analysis is promoting and facilitating possible scientific collaboration between authors and organizations [36]. This scientific collaboration can ease access to funds, and knowledge exchange, improve the efficiency of the research, share innovative ideas, and enhance scholars' communications.

Active Researchers in Cash Flow Analysis

Analysis of the co-authorship between researchers could help in sharing knowledge and experiences [37]. This analysis is implemented by VOSviewer by specifying the minimum number of published articles and received citations by authors to two and five, respectively. 41 out of 359 researchers met these conditions, as shown in Table 1. The total number of articles, total number of citations, normalized citations, and total link strength are provided for each author. Further, Figure 4 illustrates the collaborations of contributing researchers distributed in clusters.

In Figure 4, Two explicit clusters can be distinguished that have the highest density in the addressed map. The first cluster shows the collaboration between researchers: Kaka A.P., Boussabaine A.H., Odeyinka H.A., Lewis J. and Lowe J. These authors are from different institutions, which demonstrates the significance of collaboration through sharing knowledge and experiences in scientific research. The second cluster includes Elazouni A., Zayed T. and El-Abbasy M.S. As shown in Table 1, these authors have a high number of citations, which again clarifies the powerful effect of performing collaborative scientific research.

As shown in Table 1, the five top contributing researchers in cash flow analysis, in terms of received number of citations, are Elazouni A., Kaka A.P., Metwally F.G., Boussabaine A.H. and Liu S.-S. Since older published articles have more chances to be cited than recent ones, the number of received citations could be a misleading measure of the authors' contributions (van Eck & Waltman, 2014a). In this context, the normalized citations, presented in Table 1, measure the number of citations for each researcher in an average year. According to normalized citations, Elazouni A., Kaka A.P., Abrishami S., Elghaish F. and Hosseini M.R have the highest normalized citations in this domain. The results show that the most collaborative authors in cash flow analysis are Elazouni A. and Metwally F.G., according to their link strength shown in Table 1.

Table 1. Topmost contributing researchers in cash flow analysis research.

Author	No. of Articles	No. of Citations	Norm. Citations	Total Link Strength	Author	No. of Articles	No. of Citations	Norm. Citations	Total Link Strength
Elazouni A.	10	409	16.05	7	Mousavi S.M.	2	34	3.83	2
Kaka A.P.	12	385	14.87	9	Padman R.	2	34	1.29	0
Metwally F.G.	3	165	4.16	3	Abrishami S.	2	32	10.48	4
Boussabaine A.H.	2	121	2.80	1	Elghaish F.	2	32	10.48	4
Liu S.-S.	2	121	2.44	2	Hosseini M.R.	2	32	10.48	4
Wang C.-J.	2	121	2.44	2	Jiang A.	3	28	1.57	2
Price A.D.F.	2	111	4.96	2	Leung A.Y.T.	3	24	0.97	4
Cheng M.-Y.	4	104	5.78	0	Malek M.	2	24	1.32	2
Navon R.	2	96	4.48	0	Huang W.-H.	2	19	1.80	2
Hegazy T.	3	95	3.65	0	Tserng H.P.	2	19	1.80	2
Park H.K.	3	77	1.96	2	Lam K.C.	2	18	0.74	4
Han S.H.	2	74	1.79	2	Tang C.M.	2	18	0.74	4
Zayed T.	3	67	5.63	4	Carmichael D.G.	2	17	1.12	0
Lowe J.	2	56	1.85	4	Bagherpour M.	2	15	2.52	0
Odeyinka H.A.	2	56	1.85	4	Su Y.	2	13	1.34	2
Lucko G.	4	52	3.86	2	Fischer M.	2	10	5.91	2
Arditi D.	4	49	5.83	0	Hamledari H.	2	10	5.91	2
El-Abbasy M.S.	2	49	3.79	4	Konior J.	2	8	2.13	2
Afshar A.	2	37	1.28	0	Szóstak M.	2	8	2.13	2
Mohagheghi V.	3	35	4.10	2	Edwards D.J.	2	5	0.98	0
Lewis J.	2	34	1.55	2					

Norm.: Normalized.

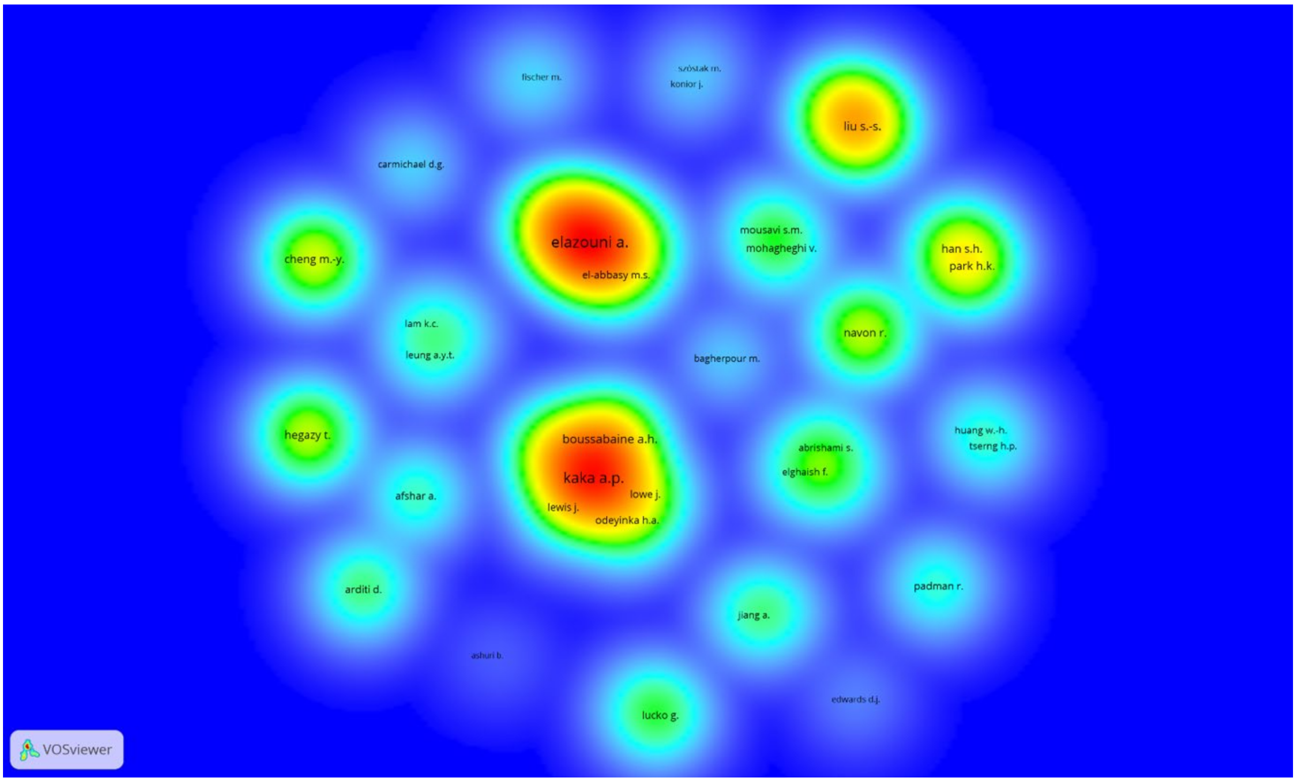

Figure 4. Density map of co-authorship network in cash flow research.

3.3. Keywords Analysis

Keywords usually reflect the main focus of the published papers [38]. Hence, a proper analysis of these keywords could help explore the main topics and themes addressed by the authors [39]. In addition, mapping identified keywords in a collection of publications could provide a comprehensive mental map of the leading research areas investigated by scholars in a specific domain (cash flow in this case) [26]. As classifying a set of publications based on topics in the systematic review is always a dilemma, keyword network visualization maps could provide clusters of different topics through text mining techniques and hence provide a basis to carry out the systematic review [17]. In this study, VOSviewer is used to develop a graphical representation of the keywords used in the cash flow research area. The presented network is obtained by setting the minimum number of frequencies to four. Consequently, 58 out of 1039 keywords meet this threshold. The network of these keywords is shown in Figure 5.

The network shown in Figure 5 is distance-based, meaning that if two keywords are close to each other, they frequently co-occur in research articles [40]. Also, the size of the keyword node in Figure 5 reflects how many times this keyword existed in the 172 research articles. For instance, Cash Flow, Construction Projects, Capital Structure, and Scheduling are represented in distinctively larger nodes than the remainder of the keywords.

Table 2 shows the frequencies and the total link strength of the top-used keywords obtained from the VOSviewer software tool. The total link strength indicates the total strength of the co-occurrence links of a given keyword with other keywords [41]. Expectedly, "Cash Flow" and "Construction Projects" are the most frequent keywords reflecting the scope of this current review study.

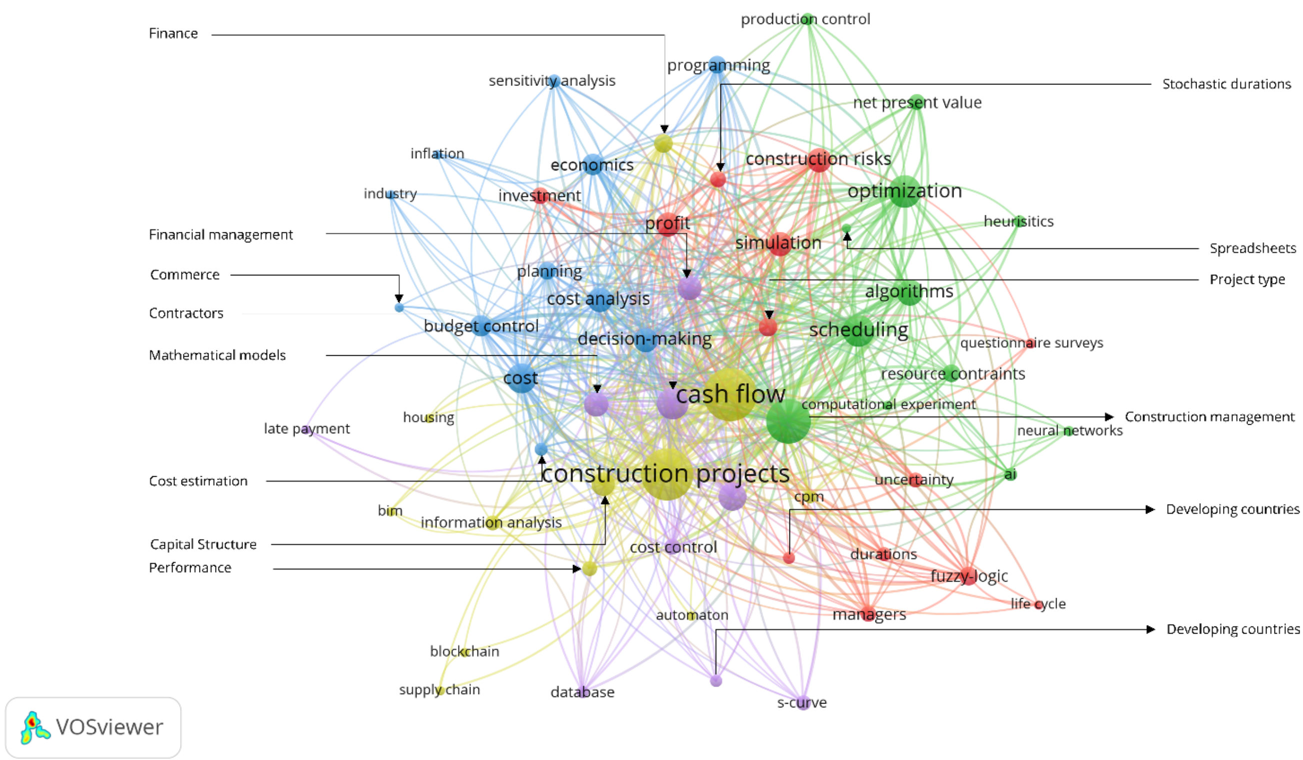

Figure 5. Network visualization map of frequently used keywords in cash flow analysis.

Table 2. Top keywords used in the retrieved articles.

Keyword	Frequencies	Total Link Strength	Keyword	Frequencies	Total Link Strength
Cash Flow	108	588	Cost Control	10	80
Construction Projects	106	613	Information Analysis	9	70
Construction Management	79	530	Performance	9	57
Optimization	41	267	S-Curve	9	51
Contractors	40	247	Uncertainty	9	69
Scheduling	40	265	Durations	8	58
Cost	35	239	AI	7	55
Forecasting	32	213	Cost Estimation	7	44
Algorithms	27	196	CPM	7	54
Construction Risks	24	130	Sensitivity Analysis	7	60
Cost Analysis	24	173	Database	6	45
Decision-Making	24	172	Developing Countries	6	38
Financial Management	24	192	Heuristics	6	46
Mathematical Models	24	191	Production Control	6	44
Profit	23	155	Regression Analysis	6	46
Simulation	23	149	Neural Networks	5	30
Capital Structure	22	172	Questionnaire Surveys	5	32
Budget Control	19	153	Automaton	4	19
Economics	18	122	BIM	4	19
Finance	15	100	Blockchain	4	12
Project Type	15	87	Commerce	4	31
Fuzzy-Logic	14	109	Computational Experiment	4	27
Planning	13	113	Housing	4	24
Programming	13	100	Industry	4	34
Resource Constraints	13	90	Inflation	4	27
Investment	12	69	Late Payment	4	21
Managers	11	87	Life Cycle	4	31
Net Present Value	11	66	Spreadsheets	4	24
Stochastic Durations	11	68	Supply Chain	4	16

In addition, the keywords are clustered by color into different groups. These clusters indicate the keywords that usually co-occur [26]. For example, Keywords such as Scheduling, Optimization, Resource Constraints, and Net Present Value are frequently used together by authors. The mentioned keywords are displayed in green color, and it is noteworthy as all of these keywords are part of the association between the cash flow analysis and scheduling, reflecting the abilities of text mining techniques of the VOSviewer tool. Therefore, the keywords are classified into five clusters. Each cluster includes several keywords shown in a particular color. The assembling of the 58 keywords into five clusters is shown in Figure 6. Each cluster is comprised of keywords that are closely related to one another. The identified keywords in each cluster form a research direction in construction cash flow. Therefore, these clusters assisted the authors in categorizing the literature in the systematic review. A detailed discussion of each cluster is provided as follows:

- Cluster 1: this cluster includes 13 keywords, including stochastic durations, construction risks, questionnaire surveys, uncertainty, and simulation. Figure 6 shows the keywords in this cluster and explains the relationships among them. The keywords included in this cluster are presented in the articles that mainly focus on the financial risks of construction projects [40,42,43]. Therefore, questionnaire surveys were heavily adopted in this cluster to explore those risk factors. Also, papers in this cluster considered the stochastic nature of activities' durations and used several techniques to consider these risks in the cash flow models [44,45]. Simulations and fuzzy logic are some of the techniques that researchers adopted to address risks and uncertainties in cash flow models.
- Cluster 2: This cluster consists of 12 keywords, including scheduling, resource constraints, construction management, AI, and optimization. Articles associated with keywords in this cluster mainly address the integration of scheduling and finance in construction projects by developing so-called Finance-based scheduling [46,47]. Notably, optimization methods have been mainly used in this cluster to find the optimum/near-optimum solution among several alternatives with accordance to cash flow functionality and develop some trade-offs between cost and time in construction projects [48,49].
- Cluster 3: 12 keywords form this cluster. The keywords in this cluster mainly indicate cost-related areas, such as cost analysis, cost estimation, inflation, and budget control. Authors in this cluster mainly focused on budget allocation and various financing options to maintain a steady cash flow during the project life cycle [50–53]. Also, "Decision-Making" is the most repeated keyword in this cluster. This is mainly because the authors in this cluster tried to determine the best financing option and improve the financing schedule for contractors [54,55].
- Cluster 4: in this cluster, the "Cash Flow" term is connected to almost every keyword in this cluster. As shown in Figure 6, keywords in this cluster are mostly technology-related, such as automation, BIM, and blockchain. Authors in this cluster tried to engage cash flow analysis with new technologies to ease and automate the payment techniques and enhance the overall performance of the cash flow in the projects [56,57], providing insight into how technologies could enhance cash flow analysis. This integration between cash flow and technologies is the fourth category of the systematic review.
- Cluster 5: A diverse set of keywords were gathered in this cluster. This cluster mainly reflects the relationship between the contractors and clients. Thus, contractors, late payments, financial management, and cost control are included in this cluster. Also, many articles related to this cluster indicate aspects related to the selection and evaluation of contractors [58,59].

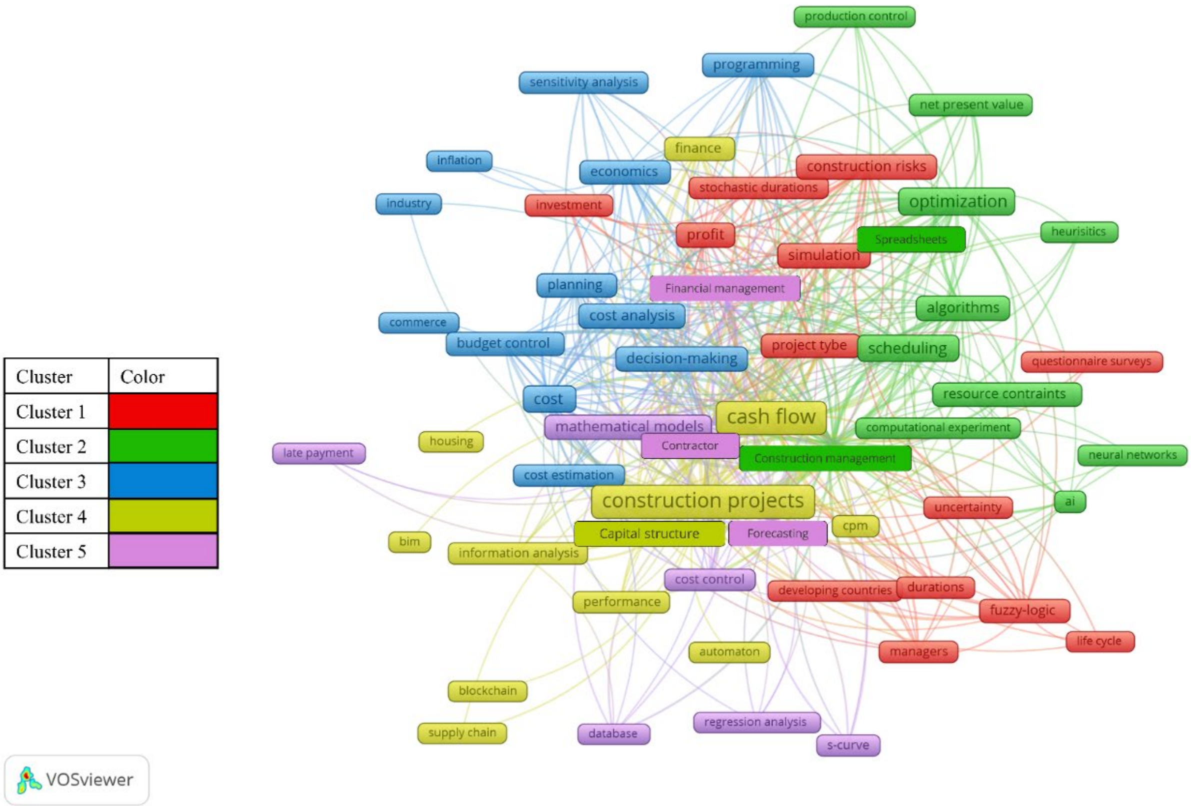

Figure 6. Clustering structure for research on cash flow analysis in the construction industry.

4. Results and Discussion of the Systematic Analysis of Cash Flow

The scientometric analysis can visualize the main aspects of a study area. However, it cannot provide a deeper understanding of cash flow analysis and a more unambiguous identification of research gaps [60]. Therefore, a systematic approach is conducted to address the limitations of the scientometric analysis. To classify the 172 articles collected, two approaches were followed. First, an in-depth reading of all articles was carried out to extract the main themes and methods. Second, the clusters resulting from the keywords' analysis conducted in the scientometric method assisted the authors in identifying the main research directions in construction cash flow research. Therefore, mapping between these two analysis types can provide a holistic classification of the previous studies. Accordingly, the 172 included articles are classified into five main categories: Cash flow factors, Cash flow-based schedule, Cash flow-based Capital structure, Cash flow-based project type, and Cash flow and digitalization. Besides, the research methods applied in each research category are presented and discussed. Consequently, the existing research gaps are identified in each category. Finally, a mapping between the different studied categories and research methods is developed to identify future trends.

4.1. Cash Flow Factors

In this category, the authors identified and assessed different types of factors that can impact cash flow in construction projects. This category also includes articles that describe the effects of negative and positive cash flow on the performance of construction projects. Figure 7 illustrates the most frequent factors that impact the construction cash flow. A complete illustration of the collected factors, along with the related studies, can be found in the Supplementary Materials (Table S1). These factors are extracted from 16 previous studies. It is worth mentioning that the factors presented in Figure 7 are not ordered by significance level. Instead, only the frequency indicator (times of factor repetition in literature) has been used to rank these factors. In order to determine the significance of these factors, subjective judgments from experts are required, which are outside the scope of this study. In one of these 16 studies, Ikediashi and Okolie [61] assessed 31 factors that impact cash flow analysis in the Nigerian construction industry using a questionnaire survey. The results indicate that the top five factors that impact the contractor's cash flow are delay in payments by the owner, delay in material delivery, lack of available resources for the contractors, exchange rate, and inflation. Also, Zayed and Liu [42] identified and evaluated 43 factors that impact the cash flow of construction companies in the USA and China. The results show that changes in progress payment, payment duration, the current financial position of contractors, and schedule delay are the most significant factors. Furthermore, in their study, a Monte Carlo simulation model was developed to assess cash-in and cash-out values, and consequently draw a cash flow profile. However, few case study projects were used to test the developed model. Most studies considered and evaluated cash flow factors by studying the impact of individual factors without considering the impact of multiple factors simultaneously. To address this gap, Le, et al. [62] comprised various factors into six groups: financial risk, retention, receivables, construction cost, during construction, and macro environment. The study examined the impacts of some/all of the factors affecting cash flow. Their results show that banks' lending interest rates, tax policies, and payment duration are among the highest impacts on the construction cash flow analysis.

Furthermore, Al-Joburi, et al. [63] assessed the impacts of negative cash flow on construction firms in Dubai. The study aimed to compare the cumulative cost and income-time profile curves with the typically estimated curves, compare the work done by contractors with the contractors' payments, and determine the available cash flow at every stage of the projects. The results showed that all the studied projects witnessed a negative cash flow for 30% to 70% of the projects' life cycle. The study addressed that the lengthy period of negative cash flow indicates the contractor's inability to proceed with the project.

Furthermore, the lack of appropriate cash flow analysis was an influential factor that affected several aspects: late payment or nonpayment in construction firms, the deviation between planned initial costs and the actual cost in construction projects, and the performance of the construction projects. For instance, Edwards, et al. [64] identified and categorized the factors that cause financial problems in infrastructure projects. They found that the client's poor financial management, included in the cash flow issues, was the most influential factor in causing distress in these projects. Similarly, Peters, et al. [65] investigated the possible solutions that could mitigate the late payment problems in construction projects. Their research showed that negotiating payment terms with clients to ease the cash flow problems was the third-ranked solution among 19 solutions that can minimize the insolvency rate of contractors' firms.

From the existing literature, several research gaps can be summarized in the following points: (1) most studies evaluated factors affecting cash flow analysis individually, while the construction industry is constantly confronted by a combination of factors; (2) the evaluation of cash flow factors in most cases is generally based on the respondent's perception, which could involve biased conclusions and subjective judgment and interpretation; (3) limited studies have studied the impacts of negative cash flow on the performance measures of the construction firms quantitatively.

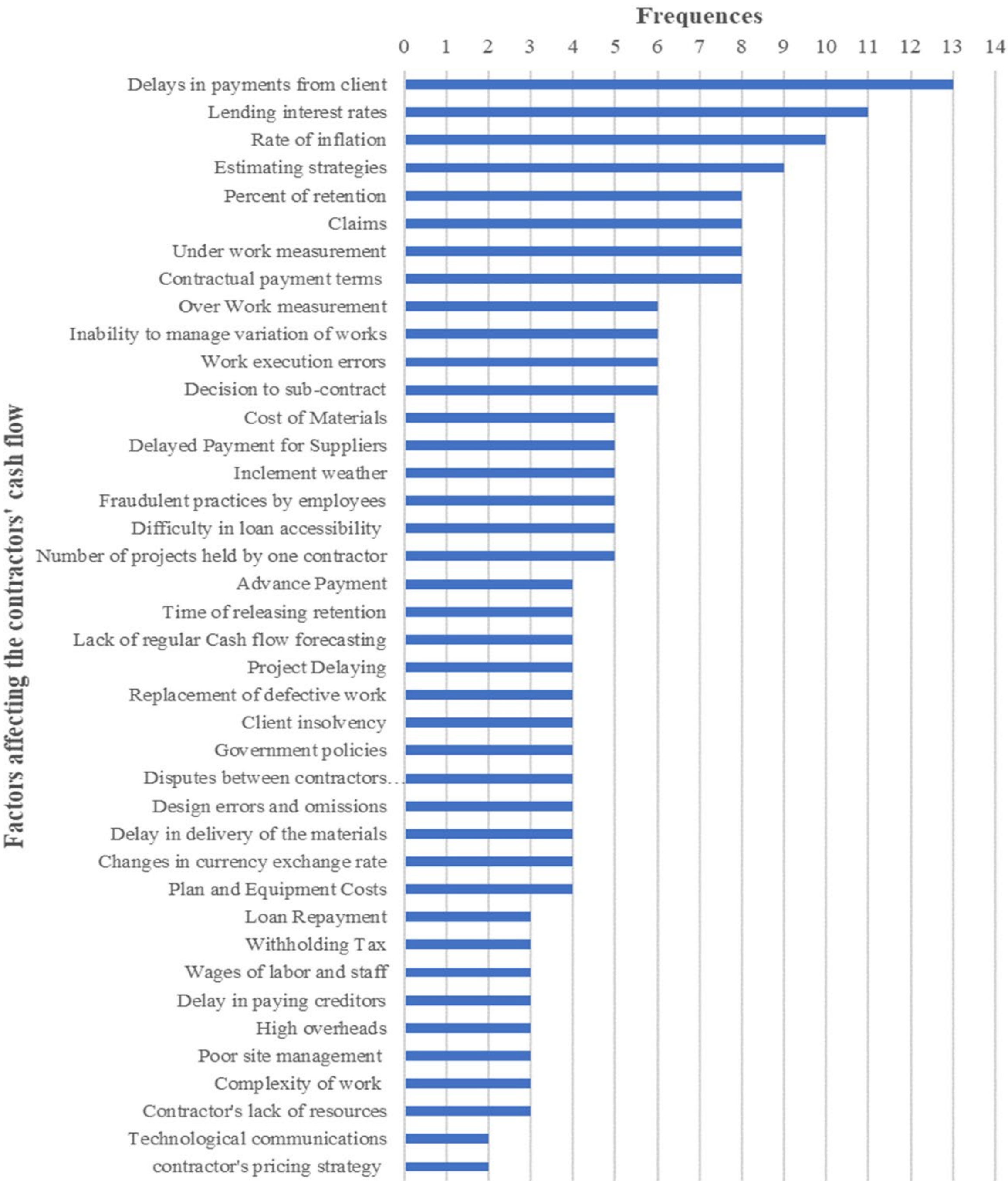

Figure 7. Factors affecting the contractors' cash flow.

4.2. Cash Flow-Based Schedule

Scheduling and financing are critical planning problems that need to be considered simultaneously [8,66]. Due to numerous uncertainties of construction projects, contractors always struggle to maintain a balance between cash-in and cash-out. Hence, the insufficient association between the scheduling and cash flow not only causes inaccurate cash flow analysis but also develops deficient schedules, increasing the failure possibility of contractors [67]. This category, therefore, deals with the articles that integrated the schedule's uncertainties in their cash flow modeling. The authors addressed different types of uncertainties in this category, such as delay in payments by the owners, resource constraints, uncertainties in activities durations, and delay in payment by the contractors to subcontractors [68–70]. Figure 8 summarizes the different types of uncertainties that are integrated with cash flow analysis and also illustrate the methods used to mitigate the impact of these uncertainties. More information on the studies that included these schedule uncertainties can be found in the Supplementary Material (Table S2).

Used methods / Types of uncertainties	Optimization models			Simulations		Technologies		Artificial intelligence		
	Heuristics methods	Meta Heuristics	Linear Programming	Beta and normal distributions-based simulation methods	Monte-Carlo Simulation	4D & 5D BIM models	Automated Computer vision-based visual basic	Fuzzy methods	K-means	Neural Networks
Payment time by the owner	0	0	2	0	1	2	0	0	0	0
Absence in updating schedules	0	0	0	0	1	0	0	0	0	0
Activities Durations	0	2	0	0	0	0	0	5	1	1
Recourses utilizations	0	4	0	0	0	0	0	2	1	1
imprecise cost estimations	0	0	0	0	0	0	0	2	0	0
Payment time from main contractor to subcontractors	0	0	1	0	0	0	0	0	0	0
external economic conditions (i.e., exchange rates)	0	0	0	0	1	0	0	0	0	0
Cash constraints in multiple projects environment	1	0	0	0	0	0	0	0	0	0
Lengthy and imprecise human inputs in cash flow systems	0	0	0	0	0	0	1	0	0	0
Sales prices (owner perspective)	0	0	0	1	0	0	0	0	0	0

Figure 8. Types of the uncertainties integrated with cash flow and the used methods.

The problem of integrating scheduling with cash flow was initiated by Elazouni and Gab-Allah [46] and was referred to as "Finance-based Scheduling". Several authors addressed the stochastic nature of activity duration when dealing with cash flow analysis. Ning, et al. [71] aimed to find a balance between cash inflow and cash outflow when dealing with stochastic durations. The author used a metaheuristic optimization model to minimize the maximum cumulative cash-flow gap. Similarly, Elghaish, et al. [56] aimed to integrate the project's schedule with the project cash flow, considering the problem of the incompatibility between the cost breakdown structure (CBS) and the work breakdown structure (WBS). The authors developed 4D and 5D BIM models and integrated them to link the cost and schedule data to the BIM elements. However, there was a considerable difference between the minimum and maximum cash-in in their study, which might need further validation.

Besides the uncertainties related to the projects' durations, many authors addressed other uncertainty types. For instance, Tavakolan and Nikoukar [72] aimed to reduce project costs by allowing variations in activities' durations depending on the changes in resource utilization. In their study, a hybrid Shuffled Frog Leaping and Genetic Algorithm (SFL-GA) was developed to accomplish two main objectives: minimizing the total cost and time of the ongoing projects; and combining the interests of returned money borrowed through various ways to prevent the cash flow from dropping below the stated liquidity limit. However, the study implemented the optimization model on a single-project basis, while construction companies might need to manage the finance of all projects simultaneously.

Furthermore, Andalib, et al. [68] addressed the uncertainty in the time interval between the contractor's expenses and the owner's reimbursement. They developed a Monte-

Carlo simulation model to represent the stochastic nature of the time interval between contractors' execution of assigned tasks and receiving their proportional payments from clients. However, the study assumed that the percentage of executive activities does not affect the owner's payment schedule. Rosłon, et al. [73] developed a multi-criteria decision-making model integrated with the Monte Carlo simulation method, intending to balance many cash flow/schedule attributes, such as subcontractors' costs and working capital.

Another direction of research in this category is related to the mitigation of humans interfering with the cash flow models. Some authors argued that manual inputs of data in the cash flow models might be lengthy and could cause delays. For instance, Ibrahim [34] created a reporting application that captures the progress data using computer vision techniques. The developed system integrated the captured progress data by computer vision with the cost/schedule control and interim payments, providing an automated reporting and cash flow forecasting system. A similar idea was presented by Cheng and Roy [74], who provided a proactive approach that monitors cash flow management as a part of the construction performance control systems. The study developed a hybrid system of artificial intelligence that combined: fuzzy logic (FL) as a tool to address the uncertainties, support vector machines (SVM) to focus on the time series of the data, and GA to optimize the FL and SVM parameters.

Regarding this research category, the literature lacks these aspects: (1) Most studies considered the schedule's uncertainties integrated with cash flow analysis based on a single project, while construction companies usually run multiple projects simultaneously. These uncertainties could have more significant impacts on cash flow when considering a multi-project environment; (2) a handful of previous studies considered the supply chain's payment terms that could undoubtedly impact the contractor's cash flow performance [75]; (3) few studies considered the relationship between the project progress pace and the financial circumstances of the project, which can lead to inaccurate decisions.

4.3. Cash Flow-Based Capital Structure

The majority of contractors experience negative net cash flow through most periods of the project's life cycle until the final payment is received [76]. Hence, contractors usually seek different funding sources to maintain high working capital to continue their business [77]. Optimizing funding sources does not only concern contractors; several articles investigated the available financing options for clients and investors that could secure their liquidity throughout the project life cycle [55,78]. Hence, this category contains articles that address the management of funding sources and capital structure from both contractors' and owners' perspectives. Figure 9 summarizes the research areas related to this category and the research methods used to address them. More information on the studies that included capital structure research areas can be found in the Supplementary Material (Table S3). Regarding the contractor's point of view, authors in this area used various techniques to maximize the available working capital. There are three different stages that need to be considered in the budget calculation for construction firms: (1) budget calculation for the current projects; (2) budget calculation of the secured projects; (3) budget calculation for unknown future projects. Kaka and Price [52] investigated the contractors' practices in financial budgeting by conducting a survey of 15 contracting construction firms in the UK. The results showed that most contracting firms suffered from an inaccurate estimation of required working capital or financing resources. The study identified two main reasons for this phenomenon: most firms fail to integrate the budget estimations of the separate projects into an overall format; the failure to appropriately consider the variations caused by the uncertain nature of construction projects. These fluctuations in working capital could easily cause the bankruptcy of contractors who could not manage to gain loans speedily [77].

Addressed Topics \ Used methods		Optimization models: Heuristics methods	Optimization models: Meta Heuristics	Optimization models: Linear Programming	Optimization models: Goal-Programming	Simulation models: Simulation-based mathematical models	Simulation models: Agent-based Simulation	Case Studies	Artificial Intelligence: T-S Fuzzy models	Hybrid Models
Financing options	Evaluation different financing options	0	1	2	0	0	0	0	1	2
	Find the optimal balance between debt and equity financing	0	0	1	0	0	0	0	0	0
	Evaluation the factoring account receivables	0	0	0	0	1	0	0	0	0
	Evaluation the Result-based Finance option	0	0	0	0	0	0	0	0	1
Budget allocation	selection the most profitable portfolio of projects considering financing options	0	0	0	1	0	0	0	0	0
	Budget allocation for a portfolio of projects	0	0	0	0	0	1	0	0	0
Contracting terms	Evaluating different payment mechanisms	0	1	0	0	0	0	0	0	0
	Negotiating different financial terms of contracts	0	0	1	0	0	0	0	0	0
Line of credit	Evaluating the activities start times to maintain the established limit of cash	1	0	0	0	0	0	0	0	0
	Minimizing the financing cost of the line of credit	0	1	0	0	0	0	0	0	0
	Selection of the most suitable line of credit option	0	1	0	0	0	0	0	0	0
Cash control	Monitoring the deviations between the planned and actual cost	0	0	0	0	0	0	1	0	0

Figure 9. Classification of cash flow-based capital structure articles and applied methods.

In this category, many studies adopted optimization methods to select the optimal funding scheme that ensures a steady cash flow through the projects' life cycle [47,67,79]. For instance, Jiang, et al. [76] developed an optimization model that respects the constraints in the financial market, including short-term and long-term bank loans. The study implemented a Pareto optimality network model to maximize the final cash availability and minimize the cost of money by trading off the profits and loan interests. However, the model did not consider any delays in the clients' payments or any other factors that may disrupt the cash flow. Besides addressing the uncertainties integrated with cash flow models, finance-based scheduling (FBS) was also used by authors to determine the most appropriate line of credit option as a funding resource to ensure steady liquidity for contractors [80,81].

From the owner's perspective, several authors investigated the most profitable investment opportunities and specified proper financial resources at the right time Etemadi, et al. [50]. Investors always face the dilemma of allocating their limited funding resources to the available projects to maximize their investment return and secure enough cash flow for the upcoming projects [82]. Moreover, investors usually experience financial distress because of several means of financial risks, leading to inappropriate cash flow [78]. For instance, Tang and Leung [55] developed a decision-support system to determine the best timing to invest in new projects and the best credit choice. The developed system combined the following: fuzzy logic to deal with unpredictable risks, an adaptive genetic algorithm to choose the optimal type of funding, and the best time to start a project. Similarly, Cevikcan and Kose [78] developed two mixed-integer linear programming models to optimize the available cash flow through a synchronized consideration of profitability and liquidity. However, the study implemented a deterministic assumption for the optimization model, which could not comply with uncertain factors in the construction industry.

Furthermore, Alshboul, et al. [83] have studied the government investments during deflations that influence the financial supply and demand in the construction industry. In their study, an integrated model was developed to quantitatively analyze the relationship between economic growth and the development of highway construction projects. Del Giudice, et al. [84] have applied fuzzy logic to evaluate various investment options when dealing with imprecise and unclear information, aiming to deal with the usual uncertainty found in the real estate market. Other considerations in owner investments, such as the relationship between a firms's disclosure quality and its cash flow, were tested by Park, et al. [85] through case studies.

The research gaps related to capital structure management are summarized as follows: (1) most studies did not consider the procurement plan when optimizing the funding resources available for contractors in construction projects; (2) the majority of researchers focused on optimizing working capital on an individual project basis and did not consider that construction firms run multiple projects simultaneously; (3) most studies did not consider the other stakeholders involved in constructions projects, such as subcontractors who could change the payment arrangements and hence change the required capital structure; (4) the previous models did not consider some uncertainties, such as the probability of client's insolvency and the unavailability of enough resources.

4.4. Cash Flow and Blockchain

As illustrated in Figure 7, several factors impact the participants' cash flow in construction. These factors include delays in payments by the client, claims, contractual payment terms, and cost-estimating strategies. All of these factors might hinder the delivery of the projects and cause delays and cash flow issues [86]. Digitalization solutions have been used by researchers to overcome some of these factors. The advances in BIM technologies have been used to improve the progress payment process [87]. Hence, BIM platforms have been used not only to digitalize building information but also to mitigate traditional construction financial system deficits [56,88]. However, BIM digital solutions are argued to be centralized, subjected to human errors, and require third party's involvement [89].

Recently, blockchain technology has been proposed as a distributed ledger that promotes information decentralization among all project participants. It not only offers a secure database but also promotes the execution of various transactions among project participants without the need for third parties [86]. As big data comes from payments transaction records, they need to be effectively traced and stored [90]. Blockchain technology provides various merits, including traceability, trustworthiness, immutability, and security. In addition, blockchain advances have promoted a platform for the implementation of smart contract solutions. Smart contracts are computerized protocols in which executable codes are implemented and run on the blockchain network [91]. Therefore, the association between smart contracts and blockchain has introduced a solution that aims to improve cash flow and payment mechanisms in construction projects [92]. This solution also mitigates some of the possible contractual conflicts and hence enhances the project delivery. Moreover, the agreed terms of a chosen contract are usually hard to be enforced and subjected to third parties, such as administrators and lawyers, which typically require monthly fees [91]. Through the association between blockchain technology and smart contracts, an endorsement policy, compliant with the contract's terms, is enforced for all participants without the need for the involvement of third parties, reducing the chances of potential conflicts and enhancing the project's financial health [86].

Various studies have investigated the possible improvement in construction cash flow through the adoption of the mentioned technologies. For instance, Elghaish, et al. [93] have developed a hyperleger fabric model (a blockchain platform) to automate transactions between project participants under the integrated project delivery (IPD) system. In their research, a risk/reward system was created on a smart contract to exploit the use of the IPD system. However, their system only considered a single project delivery system (IPD). Ahmadisheykhsarmast and Sonmez [91] presented a smart contract to improve and secure progress payment processes in construction projects and also to reduce possible conflicts without the need for third parties (administrators). However, the system required input of scheduling and cost data from a project management software. Sigalov, et al. [94] have combined BIM with smart contracts to have an enforceable and practical solution for automating progress payments between contractors and clients. However, the developed solution did not consider possible disputes, such as deadline overruns. Similarly, Sonmez, et al. [87] have investigated the association between BIM technology and decentralized blockchain to improve the progress of payment administration. However, the established payment terms (unit prices) on the smart contract were rigid and unable to be updated when changes happened.

Elghaish, et al. [86] have proposed a proof-of-concept solution to automate payment between project participants through the project life cycle, considering the traditional and design-build delivery systems. BIM models were integrated with the developed system and acted as a source for cost and schedule information. The study also considered the defects liability period (DLP) of the project by using smart contracts to manage the rest of the duties. Hameed, et al. [95] have proposed a system based on blockchain and the Internet of Things (IoT) to manage cash flow in the food supply chain. The developed system was integrated with smart contracts to automate payments among participants and enhance participants' cash flow.

The research gaps related to the association between the construction cash flow and blockchain technology can be summarized as follows: (1) the developed payment systems only considers specific project delivery system; (2) the developed payment systems by the association between BIM and blockchain technologies were partially automated, where the user needs to update the schedule and cost data manually on the system; (3) the developed systems did not consider the possible disputes among participants when developing the smart contracts.

4.5. Cash Flow Analysis Based on Project Type

Project types have a significant impact on cash flow analysis; different project types follow different cash flow profiles [96]. This category includes publications that address specific types of projects and their associated cash flow analysis. Kaka and Price [97] aimed to develop the S-curve, which is a representation of the planned financial flows on a timeline using a cumulative curve, for different types of construction projects, such as commercial, industrial, educational, and residential projects. The results showed that these varieties of projects failed to be fitted into a standard S-curve profile. Similarly, Hardy [98] investigated 25 previous construction projects and found no relevant correlation between them to be fitted into a standard S-curve, concluding that construction projects are unique and vary in terms of work progress. Hence, a part of construction organizations' failure emerges from the tendency of contractors and clients to forecast cash flows based on standard S-curves, regardless of the type and characteristics of these projects.

Regarding specific project types, Ali and Elazouni [99] aimed to manage the cash flow of repetitive, but not serial, projects. Non-serial repetitive projects are defined as projects with consistent repetition of a unit of work over the project duration [100], such as projects with multiple similar houses. Ali and Elazouni [99] argued that the existing models for estimating scheduling, and cash flow, for repetitive non-serial projects only rely on the line of balance (LOB) technique. However, this technique only assumes the sequential nature of the activities and does not consider the multiple activities that may be done simultaneously. Thus, the study integrated the LOB technique with the CPM technique to synchronize crews responsible for performing repetitive activities. The results showed that the integration of LOB/CPM with the cash flow model could estimate contractors' cumulative negative cash flow balance throughout the project life cycle and the profits at the end of the project. Similarly, Sroka, et al. [101] also addressed the cash flow and scheduling analysis of repetitive constructions projects. The study optimized the activities scheduling and cash flow using Genetic algorithm/Simulated annealing (SA/GS) algorithm. The optimization model aimed to maximize the accumulated cash flow in the final billing period, considering the finish time of construction works and the duration of billing periods.

Other types of construction projects are low-cost housing projects. [102] aimed to investigate the cash flow management of low-cost housing projects (LHPs) in developing countries. The study stated that contractors always experience cost overruns, which can be equivalent to 100% of the initial cost of the projects. The authors conducted a questionnaire survey to evaluate the interrelationships between the appropriate techniques and the possible success factors at every stage of the LHPs. Further, Alshboul, et al. [103] have developed a forecast model to provide precise cost estimation for green building projects. The study employed machine learning-based models, including deep neural network (DNN) and random forest (RF), for cost forecasting and reducing cost-related risks. Many other types of construction projects were presented by researchers in this category, including infrastructure projects [104], High-Rise apartment projects [105], and repair projects [106].

From the existing literature, there is an absence in addressing cash flow analysis for off-site construction (OSC) projects, especially modular integrated construction (MiC) projects characterized by the highest level of industrialization and prefabrication among OSC types. Compared to traditional constructions, frequently addressed in this category, the supply chain of OSC is colossally complex and contains several stages [107]. Moreover, OSC projects are constantly engaged with risk factors that impact their cost and schedule [108]. Further, contractors in offsite construction projects always deal with several stakeholders, which requires accurate forecasting and coordination of the contractor's payments, calling for more work in this field.

Other topics related to construction cash flow research are presented in the attached Supplementary Materials. This includes articles that used cash flow analysis as an indicator in the decision-making processes.

5. Trend Analysis, Future Directions, and a Potential Framework

This section summarizes the cash flow topics, their applied methods, and the research gaps in this domain, and discusses the possible future directions based on the identified gaps.

5.1. Trend Analysis

To outline the topics and methods addressed in the previous sections, Figure 10 presents a two-dimensional (2D) classification matrix of the included 172 articles on cash flow analysis. This approach can provide researchers with an inclusive view of leading trends in cash flow analysis, highlighting the research areas and methods that are frequently addressed in the literature and the others that require further attention. The two dimensions of the presented matrix can be summarized as follows: the rows represent the research areas of the construction cash flow, while the columns refer to the methods used to address them. This matrix is color-based for better visualization. Therefore, the colors used are based on the number of publications within the matrix cells. For instance, the green color specifies a high number of publications; a medium number of publications are presented in yellow; the lowest number of publications is presented in red. This mapping can help future researchers have an insight into the research opportunities in cash flow analysis. In addition to the addressed methods in the matrix (e.g., optimization and simulation methods), other methods were identified in the previous sections and grouped in the last column called "Other Methods." This group includes statical models, case studies analysis, real options analysis, and earned value analysis.

The two-dimensional classification matrix shown in Figure 10 indicates the following: (1) questionnaire surveys were mainly used in addressing the "Cash flow factors" category; (2) the highest number of publications is found in the "cash flow-based scheduling" category, with 60 articles; (3) the majority of papers in the "cash flow-based capital structure" tended to use optimization models; (4) optimization models are predominant in the "cash flow-based capital structure" category; (5) simulation methods are the most applied techniques in the "cash flow implementation for other purposes" category, which can be found in the Supplementary Materials; (6) there was seldom usage of technologies in addressing cash flow problems in construction projects.

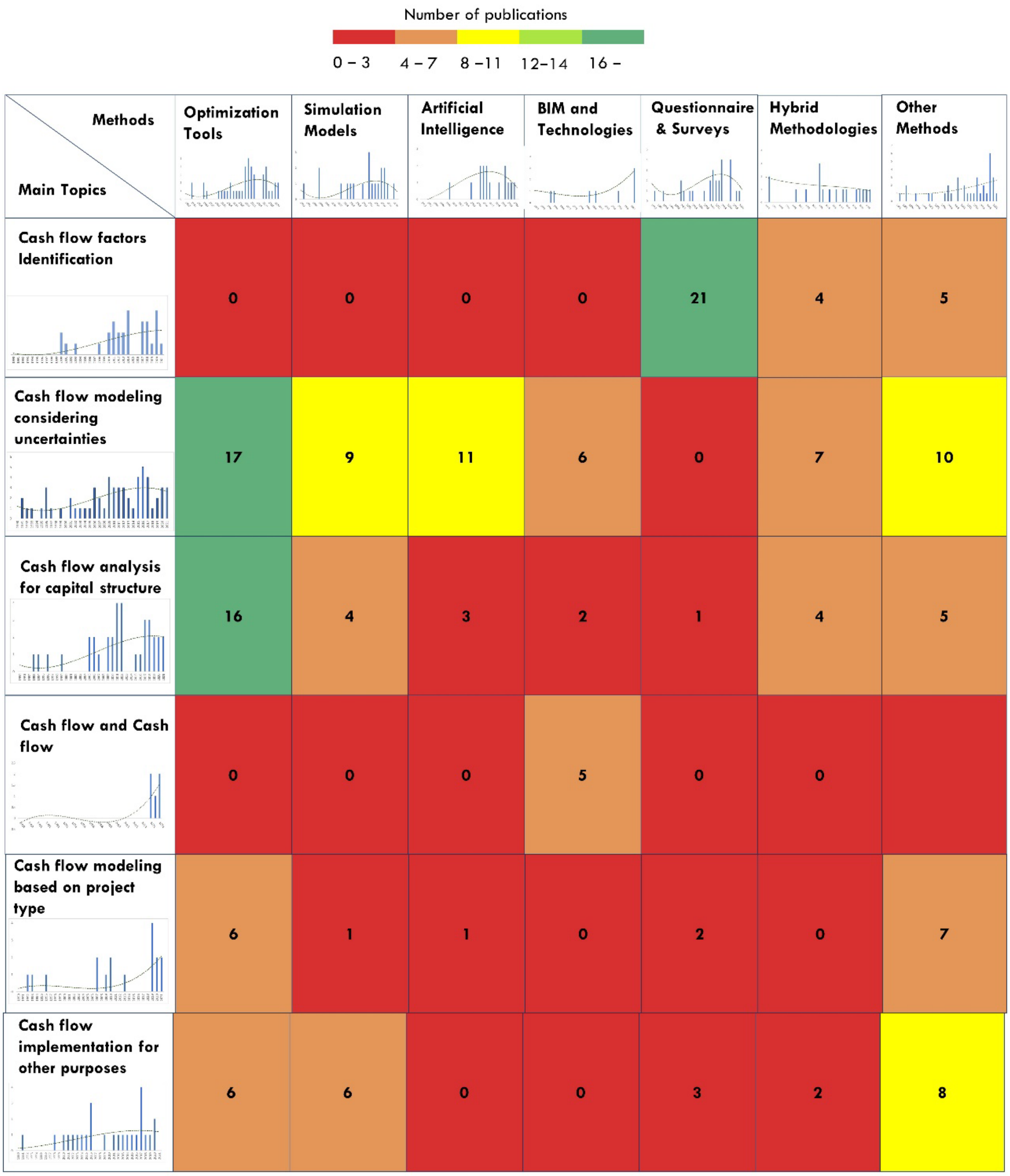

Figure 10. A two-dimensional classification matrix of main topics and methods regarding cash flow analysis.

Besides matching the methods and main topics, Figure 10 also visualizes the main trends of the addressed topics and applied methods. A graph, integrated with a 3rd-degree polynomial trend line, is presented for each research area and applied method. The *Y*-axis of each graph depicts the number of publications, whereas the *X*-axis refers to the publication year. The presented graphs show that the slope of addressing the "Cash flow factors" research area is steadily increasing, while the slopes of "cash flow-based scheduling" and "cash flow-based capital structure" have flattened over the last years. It is also noticeable that addressing "Cash flow analysis-based project type" has recently gained much attention.

Regarding applied methods, the use of optimization, artificial intelligence, and simulation methods in addressing cash flow analysis has declined over the last few years. It is also noticeable that most researchers and scholars have slightly increased their adoption of technologies, i.e., blockchain, to address construction cash flow problems.

5.2. Future Studies

In accordance with the research gaps found in the scientometric and systematic reviews, this section proposes potential areas that could extend the current knowledge of construction cash flow research. Figure 11 illustrates five potential research opportunities summarized as follows.

1. Most studies included in the "Cash flow factors" category presented the factors affecting cash flow factors in general, except [64], who addressed cash flow-related factors in infrastructure projects. Therefore, there is an opportunity for future researchers to address the cash flow factors considering a specific project type, such as OSC projects, transportation projects, high-rise buildings, etc. In addition, most techniques addressed to evaluate the cash flow factors were qualitative and based on respondents' perceptions. These techniques involve subjective interpretation and biased directions [61]. Therefore, future researchers are encouraged to rely more on archival financial reports of previous construction projects. By applying data analytics techniques to these reports, the project's participants can identify relevant factors that impact their financial health. Further, hardly any study, except for [63], has been conducted to address the impacts of having negative cash flow on construction performance. Future researchers, therefore, could seek the opportunity to investigate these negative implications to develop decision support systems to help build adequate cash flow planning while avoiding such negative impacts.
2. Regarding integrating cash flow modeling with scheduling uncertainties, most studies integrated cash flow modeling with individual risk factors except for [109]. Thus, future researchers could combine multiple risk factors when modeling cash flow to mimic the reality of the construction industry. Further, hardly any study has considered risks related to inclement weather and behavior effects (possible conflicts and disputes). Hybrid simulation methods and agent-based modeling can potentially incorporate these types of uncertainties in cash flow modeling. For instance, by employing agent-based modeling, the construction project stakeholders can be represented as agents, enabling defining their unique behaviors, e.g., delay in payments by the client. In addition, the current utilization of BIM models in integrating cash flow and scheduling, such as [56] and [88], is limited to deterministic durations. Future studies may incorporate stochastic durations in the 4D and 5D BIM models. In addition, when integrating cash flow and scheduling, the possible uncertainties in construction projects are challenging to be addressed in BIM models. Therefore, incorporating simulation approaches with BIM models can address some of these drawbacks.
3. Regarding the type of construction projects, the literature lacks studies on cash flow analysis in OSC. Despite the benefits of OSC, including waste reduction, cost/schedule savings, and minimum labor requirement, it faces financial barriers. The OSC projects are argued to be more expensive due to their high initial capital cost requirement, particularly in the earlier phase of the project [110]. Subsequently, this high initial cost can easily affect the cash flow of both client and onsite contractor, which could threaten their financial stability. Therefore, future works can address cash flow from contractors' and clients' perspectives in OSC.

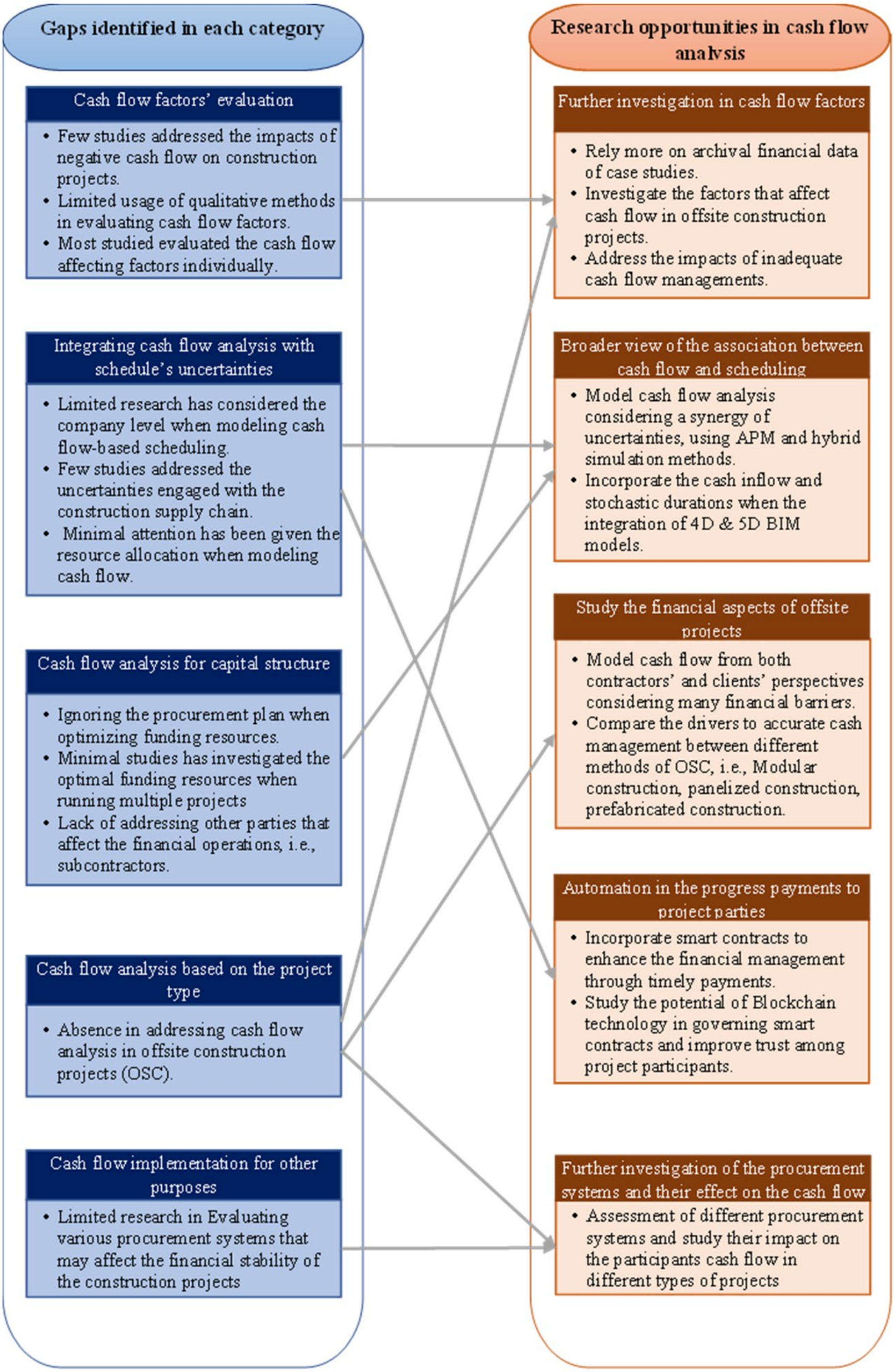

Figure 11. Summary of identified gaps and future direction in the cash flow domain.

4. In light of adequate cash flow forecasting, efficient payment practices for construction projects are necessary. In construction projects, the progress payments mainly follow a cascade nature, where the payments are delivered from the clients to the main contractors, from the main contractors to subcontractors, and so forth for the rest of the supply chain. Any deficiency in the payment process, such as late payment or non-payment, leads to unfavorable outcomes, including disputes, bankruptcies, and schedule delays [43]. In this regard, the developed cash flow systems through the association between blockchain and BIM technologies can be enhanced through the following: (1) the development of a fully automated progress payment system, where data is synchronized between BIM models and the blockchain network; (2) consideration of procurement approaches in the development of payment systems; (3) the association between the payment systems and possible disputes.
5. There is an absence found in the literature on the association between project procurement approaches and cash flow analysis. Procurement approaches can be defined as determining the contractual relationships among various project participants to build a facility [111]. These contractual relationships define the flow of cash among project participants. In some types of projects, such as OSC projects, appropriate procurement systems are ambiguous and differ from conventional construction projects due to the vast difference in processes and, therefore, affect their construction cash flow [112]. Hence, future studies can be directed to examine the effect of selecting various procurement approaches in nonconventional construction projects, namely OSC projects, on the cash flow of the project participants.

5.3. Conceptual Automated Payment Framework for MiC Projects

According to points 3 and 4 of Section 5.2, a new conceptual framework has been developed in this section to address cash flow challenges in modular integrated construction (MiC) projects, as shown in Figure 12. Cash flow issues are considered significant barriers to the adoption of MiC projects. Conventional cash flow systems are argued to be incompatible with the fragmented and complex nature of modular construction projects [113,114]. Also, compared to conventional construction methods, MiC is differentiated by more complex and fragmented supply chains. This fragmentation results in poor management of payment transactions and data sharing, hindering the financial stability of project stakeholders. Furthermore, As mentioned in Figure 7, payment delays by clients was the most frequent and highest-ranked factor that could affect contractors' cash flow [61,62,64,115–117]. As discussed in the previous section, blockchain and smart contract technologies have been promoted as potential solutions to address some of the mentioned cash flow issues in MiC projects.

Figure 12 comprises three stages to adopt smart contracts in MiC: the preparation stage, the initialization stage, and the execution stage. The preparation stage includes hiring the project's participants and agreeing on the appropriate delivery system, i.e., design-bid-build, design-build, integrated procurement system, etc. The project participants initially include a paper-based contract to define the reciprocal contractual relationships. The related project stakeholders should then register to the Blockchain platform and create a digital identity (Figure 12a). In the initialization stage, the non-owner project stakeholders specify their billing plan and link it with the billing units. The agreed conditions, billing plans, and partial payment options are then coded into a computerized protocol (smart contract). The developed smart contract is then activated on the Blockchain platform, containing the project ID, digital identities of the project stakeholders, and billing arrangement (Figure 12b).

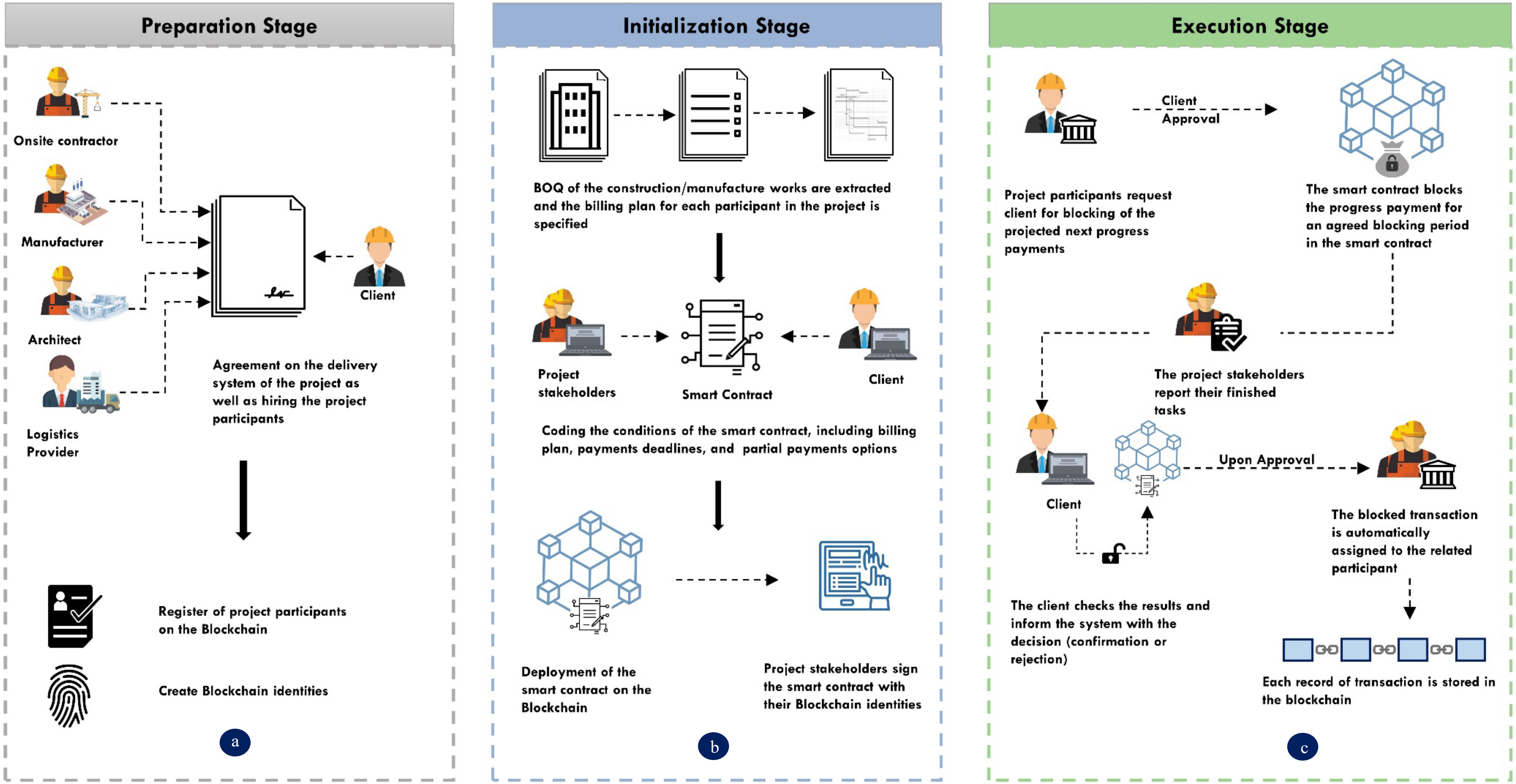

Figure 12. Conceptual framework for automating payments among project stakeholders in modular integrated construction.

The execution stage begins with the non-owner project participant requesting the owner to block the next progress payment to ensure its security. After completing the assigned tasks, the non-owner project participants report their accomplished work. The client, or the client's consultant, checks the reported tasks and notifies the system with the decision. The client's decision could follow three scenarios: confirmation, rejection, or partial payments (usually for larger tasks). Upon confirmation, the smart contract immediately transfers the progress payments to the non-owner stakeholders according to the contractual terms (Figure 12c). The smart contract subsequently blocks the progress payments of the next period, and the process is repeated. The proposed framework provides an automated, secure, and trustworthy payment platform for MiC practitioners, mitigating the need to hire trusted parties, saving administrative fees, and accelerating the payment processes.

6. Conclusions

This study is motivated by the lack of a comprehensive review focusing specifically on cash flow management of construction projects. Therefore, the study sought to quantitively and qualitatively analyze the cash flow research trends and applied methods in the construction industry. To do so, three stages were conducted in this research. First, the related articles were sourced; then, the scientometric analysis was carried out; and finally, the articles were analyzed systematically.

The search process obtained 172 related articles that were further analyzed by adopting a mixed review that integrates the merits of both scientometric and systematic approaches. The results of the scientometric analysis indicate the following: (1) cash flow analysis gained more research attention in the last two decades; (2) Kaka A.P. and Elazouni A. are identified among the most productive researchers in this area; (3) Using the analysis of keywords, the literature is classified into five clusters.

Moving to the systematic analysis, the identified clusters of keywords and the in-depth qualitative analysis facilitated the classifying of the obtained studies into five categories. These categories include cash flow factors, cash flow-based schedule, cash flow-based capital structure, cash flow analysis-based project type, and cash flow and digitalization. The number of articles that were identified in each category defined the trends of cash flow analysis in construction projects, as shown in Figure 10. The findings of the systematic review reveal the following: (1) cash flow-based schedule is the most frequent topic in the literature, followed by cash flow analysis for capital structure, cash flow' factors evaluation, cash flow-based project type, and cash flow and blockchain (2) the identified methods to address these topics are optimization, simulation, BIM and technologies (i.e., blockchain), artificial intelligence, questionnaire surveys, statical models, and case studies analysis; (3) the most frequent methods for each category are: optimization for cash flow-based schedule uncertainties; questionnaire survey for cash flow' factors; optimization for cash flow-based capital structure; BIM and Blockchain for cash flow Digitalization; and optimization for cash flow analysis based on the project type; (4) overall, the optimization techniques are predominant in the literature; (5) fast-growing research trends of adopting advanced technologies are witnessed in the last few years, referring to the potential of adopting new technologies in future research.

The study suggests future research directions for cash flow analysis in construction projects. Based on the critical analysis of the main topics and performed techniques, five future research directions for cash analysis are proposed, as illustrated in Section 5.2, and include the following: (1) further investigation of cash flow factors' evaluation; (2) enhancing the association between cash flow and scheduling; (3) studying the financial aspects of offsite construction; (4) automating the progress payments to projects' stakeholders; (5) further investigation of the effect of procurement approaches on cash flow analysis.

Furthermore, a Blockchain-based smart contract framework has been developed to provide a payment system in MiC projects that mitigates the current payment issues in MiC projects. The developed framework provides stakeholders with a timely, secure, and transparent payment platform without the need to hire a trusted third party, such as lawyers or banks, and hence saves the fees needed in payment processes.

The comprehensive review presented in this study provides several theoretical and practical implications. Theoretically, the study provides early career researchers interested in cash flow management with a summary of the topics and methods studied in construction cash flow research. Further, the researchers are provided with multiple research opportunities to extend the body of knowledge on construction cash flow research. The study also sheds light on new technologies, i.e., blockchain and smart contracts, that have the potential to address some of the research gaps in cash flow research. Practically, the study provides industry practitioners with the main issues that could hinder their financial stability and what methods researchers used to overcome these issues. The study also provides MiC practitioners with potential solutions to the MiC challenges, i.e., cash flow challenges, through adopting advanced technologies, such as blockchain and smart contracts.

Despite the contributions of this study, it has some limitations. The data collection strategy only considered the articles that were written in English. Also, there is a possibility that some articles might be left out despite adopting an extensive search strategy and snowballing techniques. Nevertheless, the findings of this research could accurately describe the trends of cash flow analysis in construction projects. Further, the classification of relevant articles based on main topics is partially based on the authors' subjective perceptions. Future research can therefore incorporate advanced text mining techniques to overcome the subjective nature of the systematic review. Also, future researchers may also include case studies to represent more realistic practices.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/buildings12122054/s1, Table S1: Factors affecting cash flow in the construction projects; Table S2: Types of the uncertainties integrated with cash flow and the used methods; Table S3: The addressed areas in capital structure management of cash flow analysis; Table S4: studies that addressed cash flow analysis as an indicator to evaluate other areas; Section S1: Other Topics related to construction cash flow References [118–155] were cited in the Supplementary Materials.

Author Contributions: Conceptualization, M.A., M.H. and T.Z.; methodology, M.A. and M.H.; investigation, M.A.; writing—review and editing, M.A. and B.T.A.; supervision, T.Z. All authors have read and agreed to the published version of the manuscript.

Funding: The authors would like to thank the Deanship of Scientific Research at Umm Al-Qura University for supporting this work by Grant Code: (22UQU4390001DSR07). Also, the authors would like to thank the Department of Building and Real Estate at the Hong Kong Polytechnic University.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

Conflicts of Interest: The authors declare no conflict of interest.

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