Corruption in Construction Projects: Bibliometric Analysis of Global Research

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Abstract: Corruption has been identified as a major problem in construction projects. It can jeopardize the success of these projects. Consequently, corruption has garnered significant attention in the construction industry over the past two decades, and several studies on corruption in construction projects (CICP) have been conducted. Previous efforts to analyze and review this body of knowledge have been manual, qualitative and subjective, thus prone to bias and limited in the number of reviewed studies. There remains a lack of inclusive, quantitative, objective and computational analysis of global CICP research to inform future research, policy and practice. This study aims to address this lack by providing the first inclusive bibliometric study exploring the state-of-the-art of global CICP research. To this end, a quantitative and objective technique aided by CiteSpace was used to systematically and computationally analyze a large corpus of 542 studies retrieved from the Web of Science and published from 2000 to 2020. The findings revealed major and influential CICP research journals, persons, institutions, countries, references and areas of focus, as well as revealing how these interact with each other in research networks. This study contributes to the in-depth understanding of global research on CICP. By highlighting the principal research areas, gaps, emerging trends and directions, as well as patterns in CICP research, the findings could help researchers, practitioners and policy makers position their future CICP research and/or mitigation strategies.

Keywords: corruption; construction projects; bibliometric analysis; knowledge map; CiteSpace

1. Introduction

Corruption is generally defined as any behavior that violates societal norms in quest of status or monetary gain [1]. In the construction industry domain, Chan and Owusu [2] succinctly defined corruption as "the abuse of assigned authority at the expense of a construction project". According to a report published by the World Economic Forum in 2016, the construction industry is among the most corrupt industries in the world. This is mainly due to the unique characteristics of the industry. For instance, contracts and projects in this industry are usually large and exclusive [3,4]. Such complexities make construction project monitoring difficult, making it easier for people to engage in corrupt practices, such as bribery and embezzlement. Furthermore, most construction projects involve many diverse and fragmented stakeholders—governments, clients, contractors, subcontractors, consultants and suppliers, among others. It is therefore often challenging to effectively trace and track payment information and the movement of funds and other resources in these projects.

Several empirical studies on corruption in construction projects (CICP) have been conducted in the past two decades [3,5–8], leading to the establishment of a rich, large body of knowledge in this area. In fact, an objective, inclusive analysis and review of this body of knowledge to inform future research, policy and practice is needed. However, to

date, this is lacking. There have been some previous review studies on CICP. For example, the short forum paper by Le et al. [9] provided a review of construction-related corruption research based upon only 56 studies. More recently, Owusu et al. [10] presented another short forum paper in which the thematic constructs of CICP were reviewed based on 48 studies. The reviews of Chan and Owusu [2], Owusu et al. [11] and Owusu et al. [12] used even smaller samples of studies (38, 37 and 39) and had narrow scopes focusing on specific aspects of CICP, namely anti-corruption measures, causes of corruption and forms of corruption, respectively. The previously reported review studies are insightful; however, they are qualitative, subjective and based upon manual literature analysis. Such reviews are prone to be biased and limited to the interpretation of a limited number of reviewed studies, which might not offer a comprehensive representation of the trends and patterns in the CICP literature [13].

To address the limitations of the previous review studies, this study aims to provide the first inclusive bibliometric study employing a quantitative technique to explore the state-of-the-art of global CICP research. It utilizes the special text-data-mining capabilities of CiteSpace to systematically and computationally analyze a large corpus of 542 CICP studies published from 2000 to 2020 to produce an objective and comprehensive portrait of the current state of research knowledge within the field. This approach is well established as a useful and valid approach to understanding the knowledge in the field, how it is structured and how it dynamically evolves over time. By bringing to light the principal research areas, gaps, emerging trends and directions, as well as patterns in CICP research, the findings of this research could help researchers, practitioners and policy makers strategically position their future CICP research and/or mitigation strategies.

The rest of the paper is organized as follows. First, the research methodology—including data collection and data analysis and visualization—is described. Second, the visualization results are presented and described at various levels of detail. This is followed by the fourth and final sections wherein the results, discussion of CICP research and the conclusions of this study are presented.

2. Methodology

2.1. Data Collection

The data used for the bibliometric analysis in this study were collected from the Web of Science (WoS) Core Collection database, which contains most influential and prestigious journals [14]. The rationale for using a WoS database is that the analysis tool used in this study, namely CiteSpace, was initially developed based only on a WoS database [15], which means that results generated by the use of WoS would be the most reliable and accurate. Moreover, to minimize potential information loss in eliminating duplications of publications from various sources, this study did not incorporate other databases, such as Scopus or Google Scholar. When referring to corruption in construction projects, some interchangeable terms were used. Following previous review studies, such as Chan and Owusu [2], Le, Shan, Chan and Hu [9], and Owusu, Chan and Shan [11], a list of keywords was created to ensure a credible approach to the search procedure. The retrieval strategy was as follows: TS = ((corruption AND construction AND industry) OR (corruption AND construction AND project*) OR (corruption AND construction AND sector) OR (corruption AND infrastructure*)).

According to the instructions of WoS, "TS" includes title, abstract, author keywords and keywords plus, and "*" means any group of characters. The time span was set to 2000 to 2020 to obtain a comprehensive sample of CICP studies published in the past two decades. The initial results obtained from the search were 583 publications. Then, journal articles in English were filtered to improve effectiveness in analyzing and interpreting the findings [14,15]. Given that it might reduce the efficiency and cost-effectiveness of analysis if more publication types were targeted, conference papers were not included [16]. Consequently, 542 publications were identified and downloaded, forming the dataset for this study.

2.2. Data Analysis and Visualization

The dataset was analyzed and visualized using CiteSpace 5.4.R1. CiteSpace is a free Java software that supports collaboration network analysis, document co-citation analysis and co-occurring keywords analysis [17]. Results generated by CitsSpace are graphs consisting of nodes and links. The nodes represent different types of entities (e.g., authors, journals and references), while the links represent relationships between nodes. CiteSpace uses co-authorship analysis to identify author collaboration and research power networks, document co-citation analysis to model the intellectual structure, co-occurring keywords to seek research topics and bursts of terms and citations to detect emerging trends. Compared to other software for bibliometric analysis, such as VOSviewer, CiteSpace presents a wider range of visualization and analysis options [18]. This software has been widely used in previous bibliometric studies within the project management field [15,19–21]. Parameter setting in CiteSpace, which should be properly set and remain consistent with research objectives, will be elaborated in the subsequent sections. Additionally, to present the findings of the study in a manner that is more organized and understandable, the results and findings of this study are elaborated and arranged following the Pereira problem solving methodology suggested by Pereira et al. [22].

3. Overview of CICP Research

3.1. Wave of Research on CICP

Figure 1 shows the variations in the total number of publications on CICP research over the period of 2000–2020. As can be seen, the findings demonstrate a gradual rate of increase in interest in CICP from 2000 onwards. Particularly, 69% of the entire 542 studies (i.e., 374) were published after 2014, plotting a significant increase for that period in Figure 1. The reasons behind this are that an increasing number of countries started funding research projects addressing the problem of CICP at the beginning of the 2010s and that the research findings were published intensively after 2014. A typical example is Professor Yun Le's team from Tongji University, China. In 2011, the team secured a research project from the National Natural Science Foundation of China to work on CICP [9]. With the support of the research project, Professor Le's team published eight papers on CICP between 2014 and 2017.

Figure 1. Annual distribution of CICP studies.
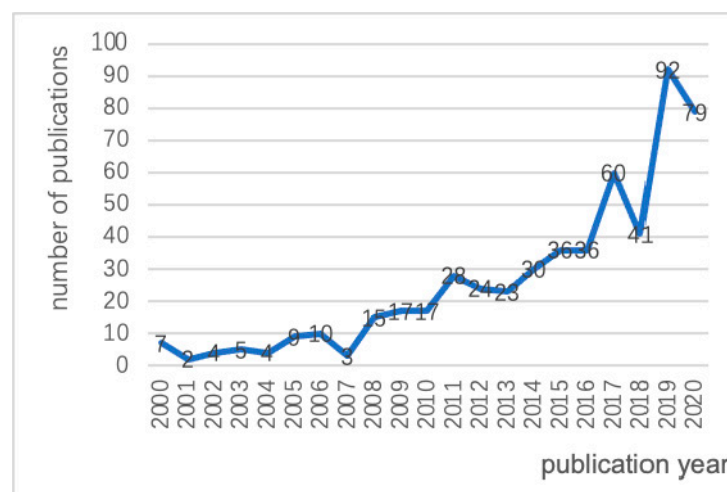
3.2. Journal Analysis

Researchers sometimes prefer journals in which they could publish their work [23]. Identifying those journals may help researchers to find suitable journals for publishing their work. The 542 publications were published in 345 journals; however, most of the journals (i.e., 257) published only one study. This finding indicates that CICP research is

relatively dispersed. Table 1 presents the top ten leading journals in CICP research, ranked based on the number of studies published. ASCE's *Journal of Construction Engineering and Management* occupied the first position with 14 studies (accounting for 2.58%), followed by: *Sustainability* (10, 1.85%); *Journal of Management in Engineering* (8, 1.48%); *Science and Engineering Ethics* (8, 1.48%); *Journal of Professional Issues in Engineering Education and Practice* (7, 1.29%); *Journal of Cleaner Production* (7, 1.29%); *Crime, Law and Social Change* (6, 1.11%); *Engineering Construction and Architectural Management* (6, 1.11%); *Journal of Development Studies* (6, 1.11%); *Utilities Policy* (6, 1.11%).

Table 1. Top ten contributing journals in CICP research.

Rank	Journals	Number of Studies Published
1	*Journal of Construction Engineering and Management*	14
2	*Sustainability*	10
3	*Journal of Management in Engineering*	8
	Science and Engineering Ethics	8
5	*Journal of Professional Issues in Engineering Education and Practice*	7
	Journal of Cleaner Production	7
7	*Engineering Construction and Architectural Management*	6
	Crime, Law and Social Change	6
	Journal of Development Studies	6
	Utilities Policy	6

Besides journals with the highest number of articles in CICP, this study analyzed references cited by the 542 publications so as to explore the journals attracting more citations in CICP research. CiteSpace was used to detect the most significant cited journals by generating a journal co-citation network, with the computing criteria described below. The top 50 most-cited articles in each year were used to construct the network, and the minimum spanning tree function was chosen to simplify the network. In addition, the references labeled "thesis", "working papers" and "no title captured" were excluded as well. The journal co-citation network in the CICP research is presented in Figure 2. In the figure, the nodes with purple rings represent journals that are cited by at least two CICP studies. The thicker the ring is, the more references the journal provides for the CICP studies. It can be observed from Figure 2 that the journal *World Development* (160 citations), *American Economic Review* (142 citations), *The Quarterly Journal of Economics* (138 citations) have the thickest rings, suggesting they provided the most references for those identified CICP studies and they were mostly related to the CICP research. Table 2 presents the top 20 most-cited journals and the numbers of articles they produced on CICP. It is worth noting that ASCE's *Journal of Construction Engineering and Management* was also among the top 10 source journals.

Table 2. Top cited journals in CICP research.

#	Cited Journals	Citations	Articles	#	Cited Journals	Citations	Articles
1	*World Development*	160	5	11	*Public Choice*	62	5
2	*American Economic Review*	142	1	12	*The Economic Journal*	61	-
3	*The Quarterly Journal of Economics*	138	-	13	*Econometrica*	61	-
4	*Journal of Political Economy*	117	3	14	*Journal of Business Ethics*	56	2
5	*Journal of Public Economics*	114	3	15	*American Political Science Review*	54	1
6	*Journal of Development Economics*	99	5	16	*Journal of International Business Studies*	52	1

Table 2. *Cont.*

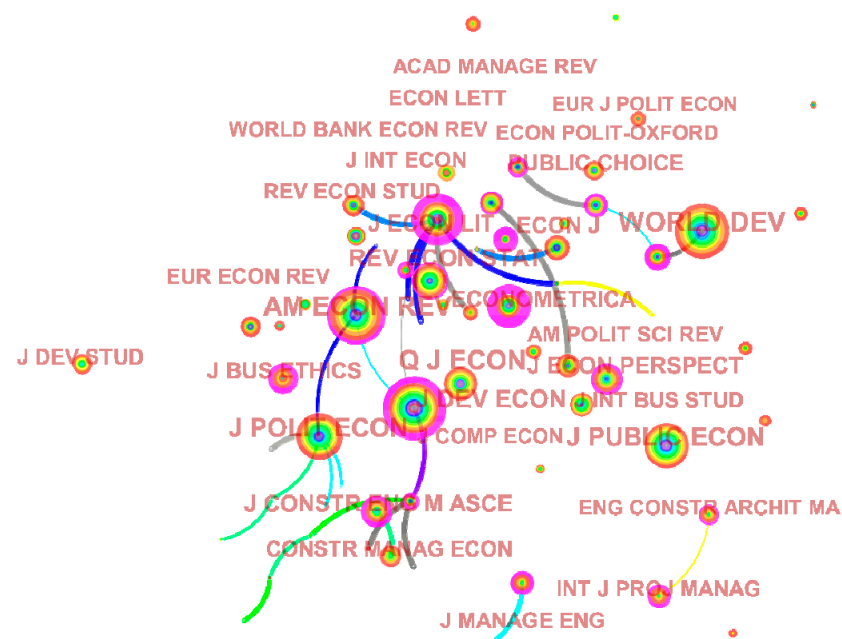| #	Cited Journals	Citations	Articles	#	Cited Journals	Citations	Articles
7	*Review of Economics and Statistics*	78	-	17	*Construction Management and Economics*	52	4
8	*Journal of Economic Literature*	75	-	18	*International Journal of Project Management*	52	4
9	*ASCE's Journal of Construction Engineering and Management*	65	12	19	*Journal of Development Studies*	51	6
10	*Journal of Economic Perspectives*	65	1	20	*The Review of Economic Studies*	51	-

Figure 2. The network of cited journals in CICP research.

Additionally, CiteSpace can generate a summary list of nodes that are associated with citation bursts. A citation burst is an indicator of notable increases in citations over a period of time [24]. Figure 3 shows the top 26 cited journals with the strongest citation bursts. The red lines show the time when bursts took place. In particular, citation bursts of significant strength in the most recent years deserve careful attention, because a new research trend often appears after bursts. According to Figure 3, *Project Management Journal* (4.22, 2017–2020), *World Economy* (3.54, 2017–2020), *Journal of Business Ethics* (3.46, 2017–2020), *European Journal of Political Economy* (6.53, 2018–2020), *Journal of Cleaner Production* (6.5, 2018–2020), *Renewable and Sustainable Energy Reviews* (4.65, 2018–2020), and *International Journal of Managing Projects in Business* (4.64, 2018–2020) are worthy of following for CICP research. Among these, *Project Management Journal* and *International Journal of Managing Projects in Business* are project management-oriented journals. Additional attention can be directed to these journals when considering submitting a manuscript about CICP.

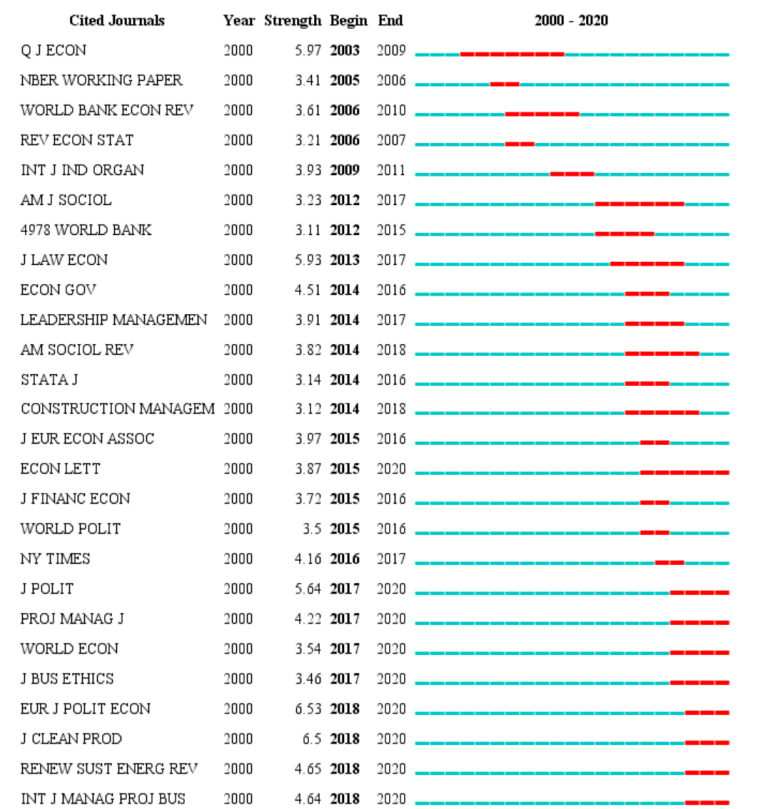**Top 26 Cited Journals with the Strongest Citation Bursts**

Cited Journals	Year	Strength	Begin	End	2000 - 2020
Q J ECON	2000	5.97	2003	2009	
NBER WORKING PAPER	2000	3.41	2005	2006	
WORLD BANK ECON REV	2000	3.61	2006	2010	
REV ECON STAT	2000	3.21	2006	2007	
INT J IND ORGAN	2000	3.93	2009	2011	
AM J SOCIOL	2000	3.23	2012	2017	
4978 WORLD BANK	2000	3.11	2012	2015	
J LAW ECON	2000	5.93	2013	2017	
ECON GOV	2000	4.51	2014	2016	
LEADERSHIP MANAGEMEN	2000	3.91	2014	2017	
AM SOCIOL REV	2000	3.82	2014	2018	
STATA J	2000	3.14	2014	2016	
CONSTRUCTION MANAGEM	2000	3.12	2014	2018	
J EUR ECON ASSOC	2000	3.97	2015	2016	
ECON LETT	2000	3.87	2015	2020	
J FINANC ECON	2000	3.72	2015	2016	
WORLD POLIT	2000	3.5	2015	2016	
NY TIMES	2000	4.16	2016	2017	
J POLIT	2000	5.64	2017	2020	
PROJ MANAG J	2000	4.22	2017	2020	
WORLD ECON	2000	3.54	2017	2020	
J BUS ETHICS	2000	3.46	2017	2020	
EUR J POLIT ECON	2000	6.53	2018	2020	
J CLEAN PROD	2000	6.5	2018	2020	
RENEW SUST ENERG REV	2000	4.65	2018	2020	
INT J MANAG PROJ BUS	2000	4.64	2018	2020	

Figure 3. Cited journals with the strongest citation bursts.

3.3. Co-Authorship and Author Co-Citation Analysis

The 542 CICP articles were published by 1183 authors. The most productive authors based on the number of publications were Albert Chan (24 publications), Emmanuel Kingsford Owusu (11), Ming Shan (10), Yun Le (9) and Yi Hu (7). The number of publications publishing the top authors was relatively small, whereas certain cooperative patterns can be found through co-authorship analysis. Figure 4 reveals the co-author relationships among major authors in CICP research. In this figure, the nodes and links represent authors and collaborations, respectively. Following Chen's [25] recommendation, the threshold function was used to construct the network and pathfinder pruning was used to simplify the network. Finally, a total of 238 nodes and 291 links were found in the co-authorship network. The scattered nodes in the figure indicate that no relationships were identified between several authors, while the closed-loop circuit between Albert Chan, Yun Le, Ming Shan and Yi Hu indicates a strong cooperative relationship among these authors. Two similar circuits exist in the relationships between Stephane Straub, Robert Gillanders and J. Luis Guasch, and between Antonio Estache, Calogero Guccio and Atsushi Iimi. The colors of the links correspond to different years from 2000 to 2020. For example, the dark grey links show that authors had collaborations in 2000, and the most recent co-citation relationships are visualized as red links. Thus, the latest collaboration happened between Albert Chan and Emmanuel Kingsford Owusu. They mainly focused on identifying causal factors, anti-corruption measures and barriers obstructing the application of anti-corruption measures in construction projects [8,11,12].

Figure 4. Co-authorship network of CICP research.

The authors whose works were cited by the 542 articles were detected by author co-citation analysis using CiteSpace, as shown in Figure 5. The node size and links represent the number of co-citations of each author and the cooperative relationships among them. As shown in Figure 4, the World Bank, an institution delivering regular reports on various topics of global economics, was the highest cited author, receiving 132 citations. Daniel Kaufmann from the Natural Resource Governance Institute and Paolo Mauro from the International Monetary Fund came in second and third position, and they received 67 and 65 citations, respectively. Daniel Kaufmann analyzed legal forms of corruption [26] and proposed control of corruption as one indicator of governance [27]. Paolo Mauro reported that corruption reduced economic growth and negatively affected the composition of government expenditure [28,29]. A significant amount of their research is published in *The Quarterly Journal of Economics*, *Journal of Public Economics*, and as World Bank reports. This could link to the earlier observation in Section 3.2 about the important journals in CICP research.
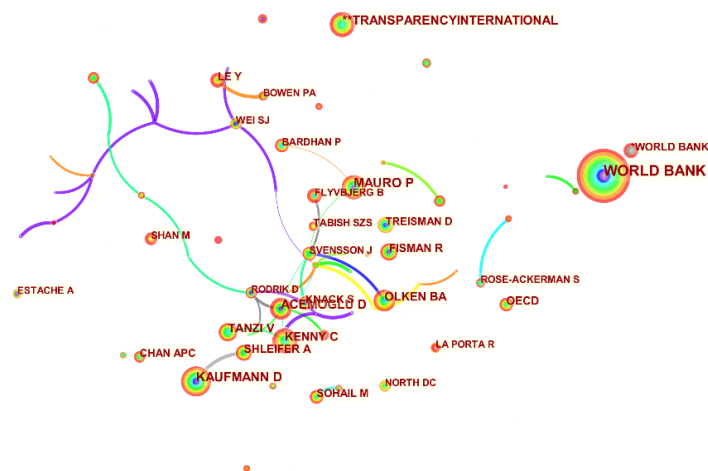
Figure 5. Author co-citation network of CICP research.

3.4. Research Power Analysis

Apart from the collaboration of individual authors, identifying the co-operation networks of research groups can detect influential institutions and leading countries. The institution collaboration network of the 542 publications on CICP research was constructed, by the threshold function and pathfinder pruning in CiteSpace (Figure 6). Larger node size reflects more publications the institution produced, and thicker links reflect a stronger co-operation relationship. As shown in Figure 6, The Hong Kong Polytechnic University stands out among other institutions with 22 publications. The following five important institutions contributing to the identified CICP research were the World Bank (17), the Australian National University (13), Tongji University (10), National University of Singapore (9) and Tsinghua University (9). In CiteSpace, betweenness centrality measures the ratio of the shortest path between two nodes in the network [18]. In the collaboration network shown in Figure 6, the nodes with high betweenness centrality are highlighted by purple rings. Evidently, the World Bank (centrality = 0.03) and The Hong Kong Polytechnic University (centrality = 0.01) held central positions in the network and connected with most of the institutions. Stanford University and the University of Maryland had connections with the World Bank before 2010, as shown by the grey links. Tongji University, National University of Singapore and Tsinghua University had connections with The Hong Kong Polytechnic University. Those collaborations occurred in recent years, as shown by the blue, orange and red links.
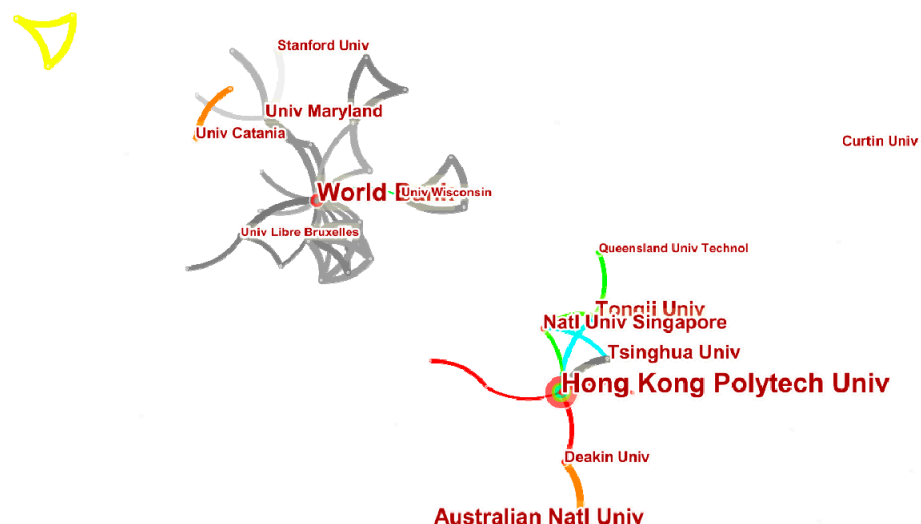

Figure 6. Institution collaboration network in CICP research.

Following the same criteria in analyzing institutions, the country collaboration network was generated and presented in Figure 7. The size of the nodes reflects numbers of articles published by the country, and the thickness of the links reflects the level of collaboration between countries. As shown in Figure 7, the top five countries contributing to the identified CICP research are the USA (165 publications), China (73), England (73), Australia (57) and Canada (26). These results show that these countries are the main research powers of the CICP field. Evidently, four nodes with purple rings in the figure have connections with most of other nodes, which means, the USA (centrality = 0.36), England (centrality = 0.33), Australia (centrality = 0.15) and China (centrality = 0.14) played an important role in linking cross-country/regional collaborations.
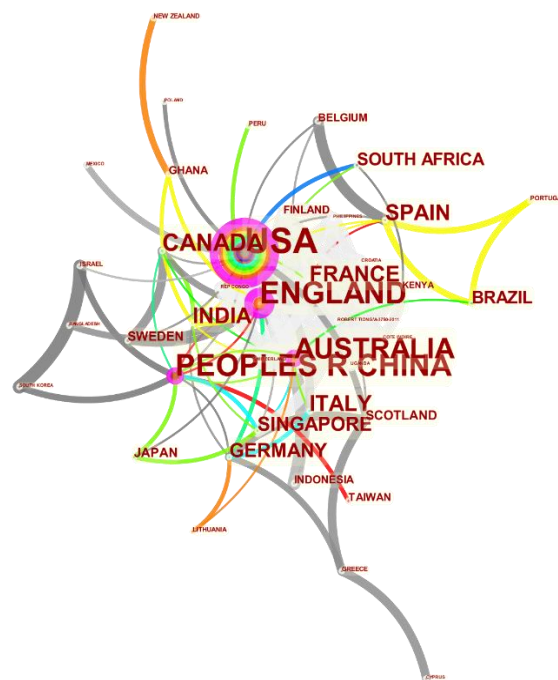
Figure 7. Country/regional collaboration network in CICP research.

4. Results and Discussion

4.1. Main Research Interests: Keyword Co-Occurrence Analysis

Keywords present research interests in each article. A network of keywords provides a picture of scientific knowledge production and suggests how research interests are connected and organized [30]. Two types of keywords, "author keywords" provided by the authors and "keywords plus" supplemented by the journals, were used to generate a network of co-occurring keywords. Figure 8 shows the network of keywords generated by CiteSpace, with 483 nodes and 223 relations. The size of a node represents the frequency of occurrence of a keyword. The top 10 high-frequency keywords are "infrastructure" (with citation counts of 66), "growth" (56), "governance" (43), "performance" (43), "institution" (40), "management" (36), "impact" (35), "determinant" (35), "developing country" (29), "foreign direct investment" (29) and "China" (29).

The frequency of the keyword "infrastructure" is the highest, which represents the research context of CICP. Infrastructure projects, which cost large sums of monies and resources, have been viewed as most vulnerable to corruption [8,31]. Keywords with high frequency, such as "governance", "management", "developing country" and "China", indicate that considerable attention was given to infrastructure in developing countries, such as China, and that corruption is mostly associated with governance and management. Furthermore, other keywords such as "determinant", "impact", and "foreign direct investment" denote that the ways in which corruption affects foreign direct investment have been well explored. For example, research from the USA [32], the Middle East and North African countries [33] suggests that corruption, as an institutional factor, plays a significant role in determining investment activities, especially investment in infrastructure projects [34,35].
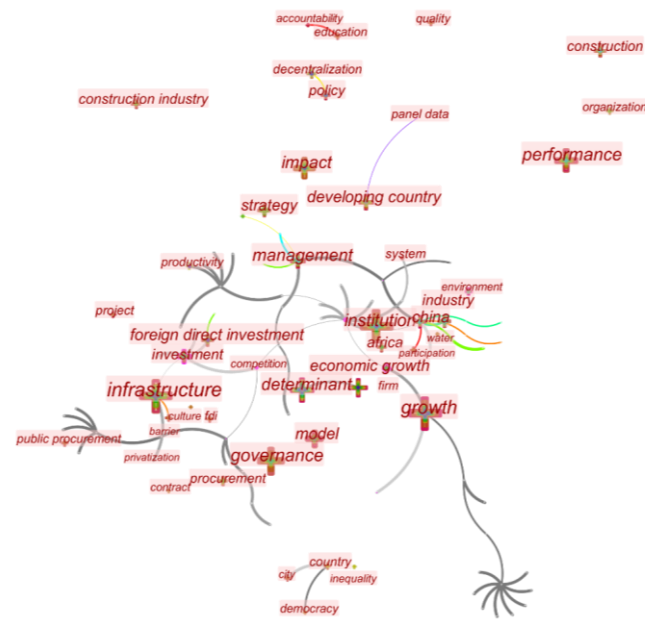
Figure 8. Network of co-occurring keywords in CICP research.

4.2. Citation Clusters: Reference Co-Citation Analysis

Generated through co-citation analysis, citation clusters reflect the intellectual base of a field of research [36]. With its clustering function, CiteSpace synthesizes the network of references that have been cited by the corresponding research and divides the network into a number of clusters, in which references on similar topics are tightly connected. Figure 9 shows the reference network in a timeline view, which exhibits 6 main clusters containing more than 10 references. CiteSpace uses two important metrics, modularity Q and mean silhouette, to assess the overall structural properties of the network [25]. The modularity Q of 0.419, which is lower than 0.7, suggests the themes of co-citation clusters are partially overlapping. The average silhouette score of 0.95, on the other hand, indicates the high homogeneity of the structures and that those coupled clusters were divided reasonably [25]. The time of publication is listed on top of the view, and clusters are arranged vertically in descending order of their size. The colored curves represent co-citation links between the references. For example, the green links indicate earlier publication than the red ones. From the timeline visualization, the sustainability of each cluster varies from 8 years to a period of over 16 years. For instance, Cluster 7, the second smallest cluster, remained active until 2019, whereas Cluster 8 was relatively short-lived. Cluster 0 contains the most important references with large nodes, which means that they are highly cited. Cluster 5 has a high concentration of nodes with red tree rings, which means that they have citation bursts.
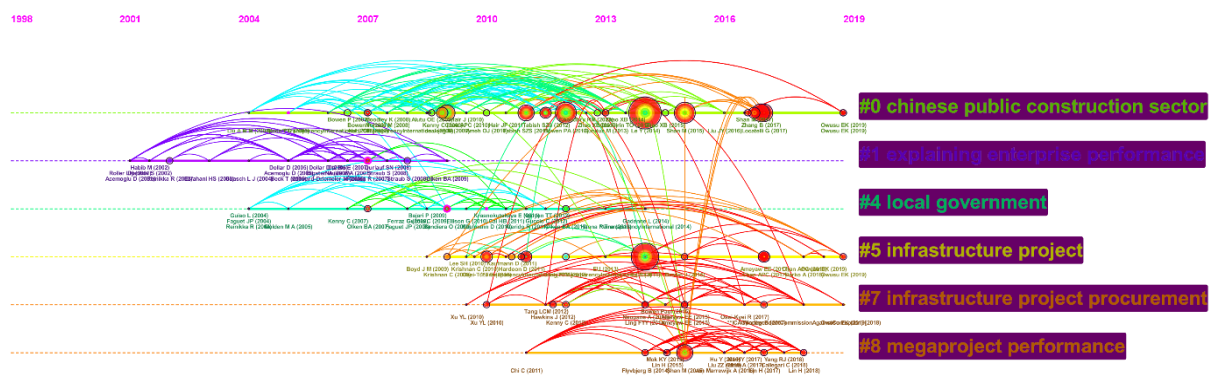

Figure 9. A timeline view of the document co-citation network in CICP research.

In Figure 9, each cluster represents an underlying theme [25]. To characterize the nature of a cluster, CiteSpace automatically extracts noun phrases from the titles, keyword lists and abstracts of publications. Among the three text-mining algorithms available for labeling clusters in CiteSpace—latent semantic indexing (LSI), log-likelihood ratio (LLR) and mutual information (MI)—LLR usually gives the best result in terms of uniqueness and coverage [25]. Table 3 illustrates the details of these six clusters, with their labels generated by LLR. For example, Cluster 4 is labeled "local government", indicating that references in the cluster are cited by articles about local government. The quality of each cluster can be reflected by their silhouette scores. With the silhouette scores ranging from 0.908 to 0.995, all six clusters are highly homogeneous. The average year of publication indicates the cluster's newness. For example, the most recently formed cluster has an average year of 2016.

Table 3. Six major clusters of co-cited references.

Cluster ID	Size	Silhouette	Label of the Cluster	Average of the Publication Year
0	44	0.908	Chinese public construction sector	2011
1	31	0.994	explaining enterprise performance	2005
4	22	0.961	local government	2009
5	20	0.901	infrastructure project	2013
7	16	0.973	infrastructure project procurement	2014
8	16	0.995	megaproject performance	2016

Regarding the results in Figure 9 and Table 3, the following discussion addresses the topics of the six largest clusters and their interrelationships:

- Cluster 0, labeled "Chinese public construction sector", contains the most important references and has drawn plenty of interest since 2007. The timeline view of this cluster reveals two periods of development. Before 2007, no high-profile references in terms of citation count were evident. After 2007, there was an abundance of highly cited references with large citation circles and bursts. Le, Shan, Chan and Hu [9] concluded their study of the forms of corruption in the construction industry by proposing three directions for future research. Shan et al. [37] explored the underlying factors causing corruption and the effectiveness of response strategies for corruption vulnerabilities in the Chinese public construction sector [38]. In addition, Owusu et al. [39] selected Hong Kong as the target city to measure the effectiveness of anti-corruption measures. Yu et al. [40] discovered a correlation between corruption and managers' age in the Chinese construction industry. Moreover, documents in this cluster studied corrupt practices in Nigerian [41], Turkish [42], Pakistani [43] and Brazilian [44] construction industries. In brief, Cluster 0 collected a majority of cited references on CICP research and focused on the corrupt practices in developing countries or emerging markets;
- Cluster 1, labeled "explaining enterprise performance", is the second-largest cluster, which is in line with the earlier observation in Section 4.1 that performance is among the top research interests. Cluster 1 refers to studies related to corruption in construction firms. The highly cited references in this cluster validated that corruption delayed economic growth from a firm-level perspective [45] and that anti-corruption policy should be designed considering market structures [46]. Dethier et al. [47] viewed corruption as one element of investment climate which has deleterious effects on firm performance. Jimenez et al. [48] revealed the role of corruption in private participation projects, which indicated that higher levels of corruption were associated with greater probabilities of failure. However, Kinda et al. [49] measured the investment climate in the manufacturing sector and found that corruption was not an obstacle to a firm's

productive performance. In summation, the cited references within Cluster 2 cover the period between 2001 and 2009. They include studies on the impact of corruption on enterprise performance;

- Cluster 4, labeled "local government", is related to the research of governance issues of corruption in public projects which are invested in by the government. Bandiera et al. [50] pointed out that corruption could lead to waste in pursuing public services. Olken [51] examined the effect of two corruption monitoring strategies and proposed that top-down monitoring by the government worked more effectively than bottom-up monitoring through grassroots participation. Then, they examined corruption in developing countries and proposed transparency reforms that might serve as effective anti-corruption policies [52]. By comparing the efficiency of central and local governments in managing infrastructure procurement [53], it was found that infrastructure investments in countries with high corruption cost more than those in countries with relatively low corruption [54]. In short, Cluster 4 collected references on CICP spanning from 2004 to 2014 that were concerned with government corruption and governance issues;

- Cluster 5 bears the label "infrastructure projects", which is similar to that of Cluster 7. Indeed, the most-cited reference in Cluster 5 explored behavioral factors influencing corruption actions [6,11] and suggested prosocial equity policies to control corruption and foster good governance, which were explained in terms of political, psychological, technical, operational and retaliatory measures [55]. A group of articles identified a set of anti-corruption measures and their effectiveness [12], compared the critical barriers obstructing anti-corruption measures in infrastructure projects between developing and developed countries [8,56] and further confirmed that construction projects executed in developing countries are relatively susceptible to corruption [4]. Moreover, Bowen, Edwards and Cattell [5] studied corruption opportunities, pressures and rationales in the construction industry and proposed possible improvements for the public sector. Overall, Cluster 5 investigated the corrupt practices and countermeasures against corruption in infrastructure projects;

- Representative references in Cluster 7 ("infrastructure project procurement") were contemporary to those included in Cluster 5. The representative references examined the extent and impact of corruption in infrastructure [57]. As the inherent characteristics of "natural monopolies", infrastructure has been regarded as fertile ground for corruption [58,59]. Several studies revealed irregularities in the procurement process of infrastructure projects [60], proposed how to design better procurement strategies [61] and provided guidance for the expurgation of corruption in infrastructure project procurement [62]. Overall, Cluster 7 covered research on CICP published around 2014, which explored the corruption in infrastructure procurement, tightly connected to research in Cluster 5;

- Cluster 8, labeled "megaproject performance", is relatively small in terms of size but high in silhouette score, which means the references in this cluster are quite similar compared to the other clusters. Studies in Cluster 8 were published around 2016 on average, which is the latest compared to the others. This result suggests that the development of megaproject performance represents an emerging trend in research on CICP. Megaprojects, which are almost always initialized by the government and built for the public [63], are very likely to be affected by corruption [31]. Corruption on the megaproject can cause cost overruns, quality issues, public complaints or massive reputational damage to a country [64–66]. However, Locatelli, Mariani, Sainati and Greco [31] concluded that scholars have paid little attention to CICP or megaprojects. Indeed, many studies called for mitigating the opportunities for corruption in megaprojects [31,67,68], which echoed those of the previous studies in Clusters 1 and 4. Other studies in this cluster reported corruption as a governance issue [69] and highlighted the social responsibility involved in improving the sustainability of megaprojects [70]. Moreover, Hosseini et al. [71] indicated that corruption should be

tackled at the preparation phase. In short, Cluster 8 collected publications focusing on corruption in megaprojects and represents an emerging trend in CICP research;

- The remaining clusters were either too small in size or too short in their duration. Certain relevant clusters did not appear in co-citation network figures, either as small sizes or as low silhouette values. For instance, Cluster 2, with 26 references, did not receive an automatic label because its references were cited only twice at most. Cluster 11, labeled "efficiency", and Cluster 19, labeled "strategies", were not displayed, because they had eight and three references, respectively.

4.3. Pivotal Papers

Besides citation clusters, reference co-citation analysis can also detect pivotal articles in a field of research [36]. In CiteSpace, documents of importance can be identified by cited frequency, betweenness centrality and sigma values [24]. The most-cited articles, as listed in Table 4, are usually regarded as landmarks because of their groundbreaking contributions. The betweenness centrality of these articles are also presented in Table 4. As betweenness centrality is a metric measuring the extent a node connects to other nodes [72], analyzing nodes with high betweenness centrality scores can reveal references located in key positions bridging two or more clusters. The ranking of reference frequency and the connections of clusters—as shown in Table 4 and Figure 9, respectively—reveal several key findings:

- The most-cited references in our dataset are Le, Shan, Chan and Hu [9] with 24 citations, followed by Bowen, Edwards and Cattell [5] with 22 citations. These two articles, along with seven other articles in the list, are in Cluster 0. This result generally concurs with the observation in Section 4.2 that Cluster 0 is the most active cluster. Moreover, the references to Bowen, Edwards and Cattell [5] have a relatively high betweenness centrality of 0.05, which means the article is in a key position connecting Cluster 0 to other clusters. By searching the links shown in Figure 9, this reference links Clusters 0 and 7. Moreover, the references to Shan, Chan, Le and Hu [38] connected Clusters 0 and 8, while the references to Le, Shan, Chan and Hu [73] connected Clusters 5 and 4. These works can be tagged as landmarks in CICP research;

- A few references in the list are from the same group of researchers. These articles reviewed the corruption research in construction [9], examined causes of corruption in the tendering process [80] and relationships between causes of and vulnerabilities to corruption [73] and investigated the effectiveness of anti-corruption strategies [38]. It was also identified in Section 3.1 that publications of the same group attracted attention since 2014;

- The common journals where these highly cited references are published include *Journal of Management in Engineering*, *Construction Management and Economics* and *Journal of Construction Engineering and Management*. This observation is partly in line with the assertions in Section 3.2, which denote the most important journals. The journal *Construction Management and Economics* does not appear in the journal list because it is not in the WOS Core Collection. However, this journal has been identified as one of the most important and top-ranked construction journals [81,82]. This result implies the limitation of our choice of search engine in this study, which should be considered for future research.

Table 4. Top 15 highly cited reference articles.

Citation Counts	Author	Title	Source	Cluster	Betweenness Centrality
24	Le, Shan, Chan and Hu [9]	Overview of Corruption Research in Construction	Journal of Management in Engineering	0	0.01
22	Bowen, Edwards and Cattell [5]	Corruption in the South African construction industry: A thematic analysis of verbatim comments from survey participants	Construction Management and Economics	0	0.05
21	Le et al. [73]	Investigating the Causal Relationships between Causes of and Vulnerabilities to Corruption in the Chinese Public Construction Sector	Journal of Construction Engineering and Management	5	0.05
19	Tabish and Jha [74]	Analyses and evaluation of irregularities in public procurement in India	Construction Management and Economics	0	0.08
17	Sohail and Cavill [75]	Accountability to Prevent Corruption in Construction Projects	Journal of Construction Engineering and Management	19	0.01
15	Shan et al. [76]	Measuring corruption in public construction projects in China	Journal of Professional Issues in Engineering Education and Practice	0	0.01
15	De Jong et al. [77]	Eliminating corruption in our engineering/construction industry	Leadership and Management in Engineering	0	/
14	Locatelli, Mariani, Sainati and Greco [31]	Corruption in public projects and megaprojects: There is an elephant in the room!	International Journal of Project Management	0	/
13	Tabish and Jha [78]	The impact of anti-corruption strategies on corruption free performance in public construction projects	Construction Management and Economics	0	0.01
12	Kenny [79]	Transport Construction, Corruption and Developing Countries	Transport Reviews	0	/
12	Zhang et al. [80]	Causes of business-to-government corruption in the tendering process in China	Journal of Management in Engineering	0	/
11	Shan, Chan, Le and Hu [38]	Investigating the effectiveness of response strategies for vulnerabilities to corruption in the Chinese public construction sector	Science and Engineering Ethics	8	0.06
10	Brown and Loosemore [6]	Behavioural factors influencing corrupt action in the Australian construction industry	Engineering Construction and Architectural Management	5	0.01

Table 4. *Cont.*

Citation Counts	Author	Title	Source	Cluster	Betweenness Centrality
10	Ameyaw, Parn, Chan, Owusu-Manu, Edwards and Darko [7]	Corrupt Practices in the Construction Industry: Survey of Ghanaian Experience	Journal of Management in Engineering	5	0.02
10	Chan and Owusu [2]	Corruption Forms in the Construction Industry: Literature Review	Journal of Construction Engineering and Management	5	/

The sigma metric measures scientific novelty [72]. Nodes with high sigma values tend to represent novel ideas and be of structural significance. In Chen, Chen, Horowitz, Hou, Liu and Pellegrino's [72] case, the highest sigma values were even associated with Nobel Prize researchers. Table 5 shows references with a sigma value higher than 1. Articles by Bandiera, Prat and Valletti [50] and Fisman and Svensson [45] have the highest sigma of 1.45 and 1.30, which means they are structurally essential and inspirational. These two references, and the reference of Olken [51], explored corruption in general, while others in the list specially focused on corruption in the construction industry. It can also be observed that three of the highest sigma references were published in 2007, and two of them were published in 2017. This result indicates that milestones in the development of CICP research occurred in both these years. The ways in which hot topics in CICP evolved will be explored further in Section 4.4.

Table 5. Cited reference articles with the highest sigma values.

Rank	Sigma	References	Cluster
1	1.45	Bandiera, Prat and Valletti [50]	4
2	1.30	Fisman and Svensson [45]	1
3	1.26	Alutu [41]	0
4	1.09	Bowen et al. [83]	0
5	1.05	Ameyaw, Parn, Chan, Owusu, Edwards and Darko [7]	5
6	1.04	Sohail and Cavill [75]	19
6	1.04	Olken [51]	4
8	1.02	Locatelli, Mariani, Sainati and Greco [31]	0

4.4. Hot Topics over Time: Citation Burst Analysis

Through keyword co-occurrence analysis and reference co-citation analysis, the main research interests and clusters were revealed. However, the process of changes in topic with time remains unclear. Citation bursts, including keyword and reference citation bursts, illustrate emerging trends in research topics [24,36]. Figures 10 and 11 display the top 17 keywords and top 14 references with the strongest citation bursts, respectively. The size of the burst strength measures innovation, which means the larger the burst value, the greater the innovation of the reference. With regard to these figures, the following observations are worth noting:

- In Figure 10, it can be observed that "growth" has the strongest citation burst (4.16), reflecting the relationship between corruption and economic growth. "Africa" and "determinant" are the most prolonged citation bursts, lasting from 2011 to 2016. Research during this period reported influencing factors in building resilient infrastructure in African countries [84,85]. The citation burst during the same period can also be denoted in Figure 11, where the references to Fisman and Svensson [45] and Olken [51] had citation bursts. Articles citing this research during this period examined corrupt practices in the construction industry in Ghana, Uganda, Turkey

and Brazil [7,42,54,58,69]. These observed results from keyword and reference bursts corroborate each other, which suggests that corruption in developing countries or emerging markets has received significant attention since 2011;

- According to Chen's [18] suggestion, emerging trends can be detected from the bursts that occurred recently. Thus, future directions in CICP research can be indicated from the keywords with citation bursts in the last 2 years. Seven keywords had citation bursts during 2019–2020, and the documents in which they appeared were examined. Large-scale infrastructure projects and public–private partnerships were identified as the main topics of those documents. This suggests that, with the wide implementation of public–private partnerships (PPPs) in infrastructure, corruption in public procurement in PPPs has become an emerging trend. For instance, Cummins and Gillanders [86] examined the role of corruption in the provision of utilities; Owusu, Chan and Hosseini [56] explored the impacts of anti-corruption barriers. This result is consistent with previous studies in which corruption in PPP projects was highlighted as one of the most important risks project managers should focus on [87,88]. Moreover, in line with the suggestions of Locatelli et al. [31] and Wang et al. [89], the effects of corruption, both positive and negative, were considered another emerging trend;

- Besides the keyword bursts, four references with citation bursts between 2019 and 2020 can be found in Figure 11. These references mainly investigated the causes of business-to-government corruption [80], corrupt practices [2,7] and the impact of a corrupt environment on megaprojects [31]. Among the references with the strongest bursts, most were published in the *International Journal of Project Management* and *Journal of Management in Engineering*. This result can be linked to Section 3.2, which presents important journals. It is worth mentioning that those four references were also pivotal references with most citations (as shown in Table 4). They still have ongoing citation bursts, which means that the topics they contain might be frontier topics.
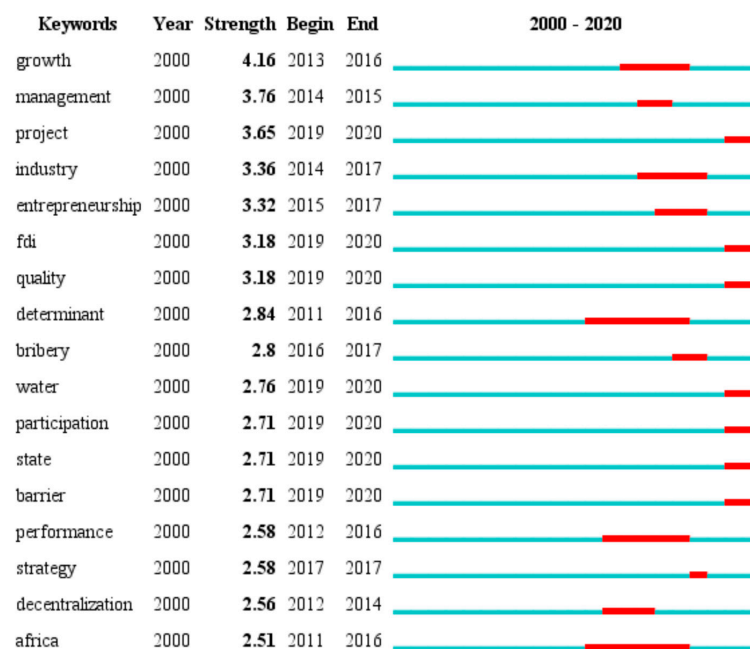
Keywords	Year	Strength	Begin	End	2000 - 2020
growth	2000	4.16	2013	2016	
management	2000	3.76	2014	2015	
project	2000	3.65	2019	2020	
industry	2000	3.36	2014	2017	
entrepreneurship	2000	3.32	2015	2017	
fdi	2000	3.18	2019	2020	
quality	2000	3.18	2019	2020	
determinant	2000	2.84	2011	2016	
bribery	2000	2.8	2016	2017	
water	2000	2.76	2019	2020	
participation	2000	2.71	2019	2020	
state	2000	2.71	2019	2020	
barrier	2000	2.71	2019	2020	
performance	2000	2.58	2012	2016	
strategy	2000	2.58	2017	2017	
decentralization	2000	2.56	2012	2014	
africa	2000	2.51	2011	2016	

Figure 10. Top 17 keywords with the strongest citation bursts.

References	Year	Strength	Begin	End	2000 - 2020
Davis J, 2004, WORLD DEV, V32, P53, DOI 10.1016/j.worlddev.2003.07.003, DOI	2004	2.99	**2009**	2013	
Svensson J, 2005, J ECON PERSPECT, V19, P19, DOI 10.1257/089533005774357860, DOI	2005	2.77	**2009**	2015	
Olken BA, 2007, J POLIT ECON, V115, P200, DOI 10.1086/517935, DOI	2007	2.74	**2010**	2017	
Fisman R, 2007, J DEV ECON, V83, P63, DOI 10.1016/j.jdeveco.2005.09.009, DOI	2007	2.72	**2011**	2016	
Kaufmann D, 2009, 4978 WORLD BANK, V0, P0	2009	3.84	**2012**	2015	
Sohail M, 2008, J CONSTR ENG M ASCE, V134, P729, DOI 10.1061/(ASCE)0733-9364(2008)134:9(729), DOI	2008	4.89	**2014**	2018	
Bowen P, 2007, CONSTR MANAG ECON, V25, P631, DOI 10.1080/01446190701225707, DOI	2007	3.1	**2014**	2017	
Alutu OE, 2007, J PROF ISS ENG ED PR, V133, P84, DOI 10.1061/(ASCE)1052-3928(2007)133:2(84), DOI	2007	3.1	**2014**	2017	
Bandiera O, 2009, AM ECON REV, V99, P1278, DOI 10.1257/aer.99.4.1278, DOI	2009	2.71	**2014**	2017	
**TransparencyInternational, 2011, BRIB PAYERS IND 2011, V0, P0	2011	2.72	**2015**	2017	
Locatelli G, 2017, INT J PROJ MANAG, V35, P252, DOI 10.1016/j.ijproman.2016.09.010, DOI	2017	3.62	**2019**	2020	
Zhang B, 2017, J MANAGE ENG, V33, P0, DOI 10.1061/(ASCE)ME.1943-5479.0000479, DOI	2017	3.09	**2019**	2020	
Chan APC, 2017, J CONSTR ENG M, V143, P0, DOI 10.1061/(ASCE)CO.1943-7862.0001353, DOI	2017	2.57	**2019**	2020	
Ameyaw EE, 2017, J MANAGE ENG, V33, P0, DOI 10.1061/(ASCE)ME.1943-5479.0000555, DOI	2017	2.57	**2019**	2020	

Figure 11. Top 14 references with the strongest citation bursts.

5. Conclusions

5.1. Summary of Findings

CICP research has attracted increasing attention in the past two decades. This study conducted the first inclusive bibliometric study exploring the state-of-the-art of existing global CICP research. It employed a scientific visualization method to highlight the principal topics of CICP research while also exploring its evolutionary trajectory. Based on analysis of a large corpus of 542 studies published from 2000 to 2020, an increasing trend of CICP research was observed. For the sake of easy understanding, the findings of this study are summarized as follows:

(1) Journal analysis revealed that ASCE's *Journal of Construction Engineering and Management* was the most contributing journal for research on CICP, followed by *Sustainability*, *Journal of Management in Engineering*, *Science and Engineering Ethics* and *Journal of Professional Issues in Engineering Education and Practice*. Researchers of CICP can direct their efforts toward these journals to generate ideas. When submitting manuscripts, researchers can also consider journals that recently experienced citation bursts, such as *Project Management Journal* and *International Journal of Managing Projects in Business*;

(2) In terms of the contributions and influences of authors identified in the co-authorship and author co-citation analyses, Albert Chan from The Hong Kong Polytechnic University is the most productive author, while the most co-cited authors are the World Bank and Daniel Kaufmann. Mostly, researchers are shown to work in isolation, though few research networks can be identified. Moreover, CICP research emanates from various countries and institutions, with the USA and China, as well as The Hong Kong Polytechnic University and the World Bank, being the largest contributors. Meanwhile, the USA and the World Bank play the role of a hub, linking research from other countries and institutions;

(3) The keyword co-occurrence analysis revealed that governing corruption in infrastructure industries of developing countries received much attention in research on CICP. Moreover, since construction projects have attracted growing foreign investment, exploring how corrupt practices affect foreign direct investment is also an important research topic. Based on document co-citation analysis, six typical clusters were generated. Major specialties of the clusters of CICP research can be categorized as corrupt practices in developing countries or emerging markets (Cluster 0), corruption impact (Clusters 1, 4 and 8) and casual factors of corruption and anti-corruption strategies (Clusters 5 and 7). Few studies focus on CICP in developed countries. This finding indicates a future research direction, which might involve comparative studies between different economies.

(4) Moreover, recent burst keywords illustrate that topics about public–private partnerships, barriers and effects might be emerging trends. It is worth noting that those recent burst keywords did not appear in the list of high-frequency keywords, which reflects gaps

in the literature on CICP. The focus of most of the articles was corruption in traditional infrastructure projects, whereas the association between corruption and PPP/megaprojects received less research attention (this finding can also be tested in burst references).

5.2. Implications and Limitations

The bibliometric analysis in this study was an exploratory attempt to provide a visualization of the basic characteristics of the CICP literature. Computational, quantitative analysis of the literature helped reduce the influence of subjective judgments associated with manual, qualitative analysis of the literature. The findings of this study provide valuable information for researchers, practitioners and policy makers, allowing them to gain an in-depth understanding of CICP research. In theory, the findings of the presented study are reproducible with minimal subjective judgment. In practical terms, this study emphasized that public infrastructure projects face and should respond to challenges of corruption. This research could facilitate practitioners and policy makers' attempts to tackle corrupt behaviors in construction projects through designing suitable anti-corruption strategies.

Despite its contributions, this study has limitations. First, the findings of this study might not fully reflect the entire literature on CICP, as the reviewed articles were collected only from the WoS Core Collection. Some quality publications indexed in other databases, such as Scopus, may have been omitted. Second, the emerging trends and research patterns in the CICP literature presented in this study were produced by the CiteSpace program, which might have varied slightly due to different settings applied to the software by users with different understandings of CiteSpace.

5.3. Future Research Opportunities

The bibliometric analysis depicted in this study is essential in revealing the relevant gaps and future research opportunities about CICP. The keyword co-occurrence analysis and the analysis of reference co-citation revealed that CICP in developed countries, and accountability systems for CICP, were not receiving much attention. Therefore, potential research efforts could be directed toward the investigation of CICP in developed countries and the enforcement of accountability in construction projects to reduce corruption. Moreover, burst analysis revealed that investigating how corruption context affects megaproject performance, and whether greater control of corruption attracts more private investment, could be a pathway for future research efforts on CICP.

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