Interrelations between construction ethics and innovation: a bibliometric analysis using VOSviewer

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Abstract

Purpose – Many companies invest in innovations because of the inherent benefits, and research on innovation has increased over the year. However, the vast majority of research papers deals with purely technical matters. There seem to be growing concerns over ethical issues in adopting innovations in the construction industry. This extant review of literature aims to analyse the interrelations between the concepts of ethics and innovations in construction research to understand the advances of current scientific production and future lines of research.

Design/methodology/approach – Thus, this work presents a bibliometric analysis covering articles obtained from the Web of Science Core Collection Database published between 1995 and May 2021. A sample size of 5,786 research papers relevant to the study was evaluated using VOSviewer software.

Findings – The results of the analysis shed light on the evolution of the connection between the two concepts. The study highlighted Heng Li as the most productive author. The country with the most publications and citations is China. The most productive institution is the Hong Kong Polytechnic University. The results revealed a limited intellectual exchange and lack of cohesion characterising the two concepts (ethics and innovation), resulting in a situation whereby innovation-related researchers tend to follow personal trajectories in isolation from ethics-related researchers in the construction field.

Originality/value – This is probably the most comprehensive scientometric analysis ever conducted to examine the theoretical relationship between ethics and innovation in construction. This study adds to the so far limited knowledge in the field and provides insights for future research. Overall, this review may spur future research on dyad investigation of ethics and innovative related themes in construction such as ethics and sustainability, ethics and sensor-based technology and ethics and innovative safety approach.

Keywords Bibliometric, Construction, Ethics, Innovation, Sustainability, VOSviewer

Paper type Literature review

Introduction

Innovative development and automated decision-making have become increasingly popular with the growth of the internet, big data, cloud computing and other technologies

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(Li *et al.*, 2021) . Several applications have been developed that brought significant changes to the entire human race. Simultaneously, the distinction between the physical world and the person is increasingly blurred, resulting in a sequence of ethical crises and many impediments to the growth of institutional systems (Deng *et al.*, 2020). The role of innovation has been continually emphasised in construction as a vast and diverse business field that is more demanding than ever before (Meng and Brown, 2018). Robust ethics is an essential criterion for developing the construction industry in the 21st century (Aouad, 2018). Fobel and Kuzior (2019) view the future of construction as a challenge to science and technology and as a question of ethical interest and possible ethical risks. Several authors (Blayse and Manley, 2004; Davis *et al.*, 2016; Lim and Ofori, 2007; Meng and Brown, 2018) have studied construction innovation, but researchers tend to underestimate the ethical dimension as an essential part of creative strategies, risk mitigation or prevention. However, there is an asymmetry in the majority of the field's debate. Even if the direction of progress is sometimes questioned, it is debated mainly as a catalyst for progress (Land, 2004). In general, innovation is seen as something that supports society as a whole. Also, many scholars have examined the topic of construction ethics (Oladinrin and Ho, 2016; Fellows *et al.*, 2004; Tow and Loosemore, 2009; Mason, 2009; Vee and Skitmore, 2003). Previous studies have applied a series of theories and inquiries to help explain the relationship between innovation and ethics (Fontrodona, 2013; de Kreuk *et al.*, 2009; Brusoni and Vaccaro, 2017). Technology-based businesses face the same ethical challenges as other manufacturing or engineering firm regarding product quality, efficiency, and environmental concerns. This ethics aspect of technology has gained a great deal of coverage in the literature of innovation business (Fassin, 2000).

The development of several study streams in academic literature does not appear to result in a clearer understanding of the interaction between construction innovation and ethics because of the multifaceted nature of the field. In some approaches, ethical innovation is treated as abstract and decontextualised, disconnected from its institutional, socioeconomic and cultural macro-context. This could explain why, at the moment, analysis on the convergence of the two areas is only in its early stages. Despite the apparent interest in innovation in the scientific literature and the well-established field of ethics, the two themes are seldom merged in scientific research. The number of studies dealing simultaneously with innovation and ethics is a minor fraction of the overall discussion around the two themes, which is true in construction research. Besides, there seems to be a lack of research, especially in the construction field, on how innovation could be a part of the apparatus of unethical practices and a tool used to challenge the established system of organisational values. Due to the dynamic ethical issues and the strong relevance of innovation, understanding this area's overall structure becomes challenging, if not impossible, without a more in-depth analytical approach. Such an approach is critical because many issues are at the centre of innovation and ethics discussion in construction that necessitates sustained engagement. For instance, the provision of any innovative solutions is inextricably linked to the implications of their usage, and in some cases may even prevent their use (Hanekamp, 2005). Unfortunately, there have not been bibliometric analyses that discuss the evolution of ethics and innovation in construction. That is the void in the emerging literature that we want to fill by offering detailed insights into publication trends in this domain. An analysis combining ethics and innovation in construction, using bibliometric techniques, has not yet been conducted, to the best of the authors' knowledge. Ultimately, innovation and ethics are multi-level phenomena. More attention to relevant context that links ethics and innovation can help advance research in this domain. Therefore, this study aims to analyse the relationships between the concepts of ethics and

innovation in construction to understand the advances of current scientific production and future lines of research. We used bibliometric analysis techniques to examine both the ethics and innovation literature published between 1995 and 2021 and the network of researchers engaged in its production.

Ethics in the construction industry

Ethics is defined as a set of guiding moral principles that an individual considers in evaluating an action or situation (FMI Corporation, 2004). In the construction industry context, Kilcullen and Kooistra (1999) described engineering ethics as a set of principles that directs corporate actions to reflect a concern for society as a whole while seeking profits. Due to several unethical practices, engineering ethics has become an organisational priority (Maqsoom *et al.*, 2020). According to Bishop (2013), a code of conduct is developed due to increased intolerance in society and cunning individuals' reckless and selfish activities. Lloyd and Mey (2010) opined that the characteristics of the organisation influence the ethical program. Nonetheless, the construction business is regarded as one of the most corrupt in the world due to extensive unethical activities (Sohail and Cavill, 2008). Many researchers have examined the subject of ethics in the construction industry (Aouad, 2018; Oladinrin and Ho, 2016; Mason, 2009). Bowen *et al.* (2007) posited that unethical behaviour had harmed the integrity of the construction sector in both developed and developing countries. Most countries have a negative image of the building sector in terms of ethics. The concerns include corruption, malpractice, and mismanagement; exploitative business tactics; and a lack of accountability for the well-being of its own staff and other stakeholders. Recent occurrences, such as the Grenfell Tower disaster in the UK, incidents of bad building work and the collapse of constructed goods in various nations, modern slavery, and a lack of worker protection, have brought the public's concerns to notice. It is believed that up to one-third of government building investments are wasted due to corruption and incompetence (Egbu and Ofori, 2018). Tow and Loosemore (2009) discovered that the construction industry has a poor ethical culture. Ethics is articulated and applied to avoid corrupt activities and promote stakeholder confidence (Oladinrin and Ho, 2014). As a result, it is fair to anticipate that engineering ethics will positively moderate the impact of innovations in the construction industry. Therefore, It is appropriate and timely to explore the state of ethics in the construction industry around the world *vis-a-vis* innovative development.

Innovation within the construction industry

Innovation has been described as the consequence of the introduction of new products, processes, markets, organisational structures and new services (Gajendran *et al.*, 2014). The definition of innovation that is widely accepted within the construction industry is that of Slaughter (1998), who defined innovation as the actual application of a nontrivial change and improvement in a process, product, or system that is original to the institution generating the change. Building information modeling (BIM) and partnership are two examples of construction innovation methods that have had a significant influence and attention over the last decade (Ekeskär, 2019). The construction industry is one of the crucial sectors in modern economies. The greater the amount of innovation in the construction business, the more likely it will contribute to economic growth. Unfortunately, in most countries, there is a widespread view that the sector is not inherently innovative and that there is considerable opportunity for development (Blayse and Manley, 2004). Given the structure of the industry and the nature of the construction sector, criticism of the sluggish rate of innovation in the construction industry may be unfounded (Davis *et al.*, 2016). According to Manley (2008), construction innovation may be classified depending on

technological and organisational factors. Technical innovation is typically impacted by the managerial and economic structure's orientation. On the other hand, organisational innovation includes the use of business practices, such as when a new method is introduced into a system that substitutes an existing established pattern of conventionally accepted products and procedures. Blayse and Manley (2004) identified six major factors that influence construction innovation: clients and manufacturers, the structure of production, relationships between individuals and firms within the industry and between the industry and external parties, procurement systems, regulations/standards, and the nature and quality of organisational resources. Innovation is critical for increasing productivity and progress in several areas of the economy, including the construction industry (Davis *et al.*, 2016). The development and successful application of innovation can bring significant competitive benefits to engineering and construction organisations (Blayse and Manley, 2004). The literature well recognised that there is a rise in queries about how innovation processes might lead to improved business results for construction organisations (Hartmann, 2006; Davis *et al.*, 2016). However, the loosely tied structure of construction firms, largely Small and Medium Enterprises (SME's), providing "projects" through partial involvement, along with the separation between project innovation and company innovation, makes it challenging to extract innovations in a meaningful way. The issue also resides in conceptualising, describing, expressing, and judging construction innovation (Davis *et al.*, 2016).

Relations between ethics and innovation

On the surface, it might seem that innovation and ethics are opposed ideas. Ethics has a prescriptive component that sets out what we can and cannot do, limiting our scope of action (Fontrodona, 2013). Viewing ethics from this perspective might make one believe that ethics could limit innovation. By its experimental nature, innovation often involves risks associated with its development and implementation (Greene, 2003) but ultimately leads to doing things differently, breaking the mould, and overcoming barriers (Fontrodona, 2013). Ethics cannot be limited to a legalistic interpretation of human conduct, let alone a pessimistic view that describes ethics as a set of prohibitions. A constructive, systematic understanding of ethics would lead one to recognise the close relationship between ethics and innovation: that innovation, like all other human endeavours, is profoundly embedded in ethics and that ethics stimulates and promotes innovation. In this sense, it is essential to differentiate between (1) "theoretical" or "pure" ethics, which is the reasoning for the principle of "value" or the concept of "good" in general; and (2) "practical" or "applied" ethics, which is more closely related to specific realms of life such as; ethics of innovation, construction ethics, ethics of technology. However, philosophical reflections in applied ethics may contribute to the formulation of constructive moral schemes in which such domain-specific rules (on a high degree of generality, free of case-specific details) are formulated (Gruner, 2008). The formation of positive ethical networks is essential in developing sustainable innovations in response to external crises (Dossa and Kaeufer, 2014). Ultimately, ethics is innovation because it allows one to look at things from a new perspective, thereby bringing additional facets to decision-making processes. Above all, it encourages a rethinking of the essence and intent of industry that is more in tune with the sensitivity and demands of contemporary society (Fontrodona, 2013). Gruner (2008) posited that technology innovation had triggered innovation in ethics because the "old" ethics is no longer adequate to deal with moral challenges of a "modern" society raised by the introduction of new technologies.

Furthermore, ethics offers science and technological innovation with reference points for knowledge development, as technical capability does not substitute but instead allows one to challenge ethical adequacy and political expediency (Fontrodona, 2013). Therefore, ethics should be of concern to innovation studies as a collection of phenomena likely to have an overt or indirect impact on innovation. Despite many previous studies on ethics and innovation with significant results over several years, it is evident that the dyad of ethics and innovation is relevant in the current construction research trends. The challenges of ethical innovation research direction in construction and the lack of bibliometric analysis justify the need for this study. This study is timely because it offers a systematic literature review on recent and prospective research developments in ethics and construction innovation.

Methodology

Separating the most relevant documents from the vast amount of literature takes much time. The amount is still growing, making it increasingly difficult to follow the evolution of a discipline using conventional methods, particularly in multidisciplinary fields (Zou and Vu, 2019). Hence, bibliometric analysis was employed in this study. The bibliometric approach is valuable in this sense because it allows one to derive the essence of a research domain from a large amount of data. It enables the investigation of information structure, the development of research areas, and the capture of research subject interdisciplinarity (Pauna *et al.*, 2018; Zou *et al.*, 2018). Bibliometric analysis generates a map that reflects the evolution of a research field and the intellectual structure of a scientific domain. It is a valuable guide for keeping track of science and technology's frontiers, illustrating scientific exploration directions, and aiding researchers in making decisions. The most noteworthy aspects of science can be visualised by mapping what is known to science, assisting researchers in mining, analysing, and displaying the information and interrelationships. The research methodology was planned to cover the following stages, as suggested by Börner (2010) - data collection and analysis; mapping tool selection; visualisation; and presentation, interpretation, and discussion of findings.

A bibliometric analysis of the relationship between ethics and construction innovation adds to the literature in two respects. First, the bibliographic approach complements previous qualitative studies. We take a broader scope to have a more significant sample of documents than previous reviews (Torresen, 2018; Reijers *et al.*, 2018), resulting in a more comprehensive and objective exploration of the history and past evolution ethics-innovation debate. Second, the bibliometric approach allows for a more accurate assessment of the future of ethical innovation in construction research. We hope to introduce a paradigm shift from traditions to future trends by highlighting the current and future development areas for the continued evolution of the ethics-innovation debate. This review demonstrates interrelations between ethics and innovation in construction; how the theory or scientific application may be used to link distant and disconnected viewpoints; how new areas of study will benefit from more developed ones; what are the topics of development of ethics and innovation; and how these will be further stimulated in the 21st century. We use VOSviewer to conduct quantitative analysis on the relevant literature to create a knowledge map and include the most up-to-date advancement and frontier hotspots in ethics and innovation studies in construction. These are intended to serve as guides and a foundation for further research.

Data collection

We used Google Books Ngram Viewer, a modern platform that works on a 361 billion English words database, to quickly recover data on keyword frequency in a diachronic

context (Zięba, 2018). Figure 1 shows a graphical representation of how often the terms "ethics" and "innovation" have been used in the literature. There is a point of intersection in 1995; hence, for more profound research, we search for literature from 1995 to 2021. We used Web of Science (WoS) core collection to extract bibliographic data because of its advantages over other bibliographic databases such as Scopus. First, the citation matching algorithm seems to need improvement in Scopus compared with WoS (Valderrama-Zurián *et al.*, 2015). Second, duplicate publications in Scopus constitute a significant data quality issue (Van Eck and Waltman, 2017). In terms of WoS, a general drawback is that its coverage of the social sciences and humanities is limited (Mingers and Leydesdorff, 2015). Although the literature discussed by this paper overlaps with the debate on responsible research and innovation, its breadth is significantly narrower because it only considers literature that deals explicitly with ethics rather than the wide range of possible research and innovation impacts in general.

Following the earlier review study (Meseguer-Sánchez *et al.*, 2021), we searched for the topic: "ethic*" OR "technolog*" OR "innovation*" OR "modern method*" in the period 1995–2021. These keywords were, therefore, used in this study as the search keywords. In addition, we searched for "ethics AND innovation" to include papers that have addressed both ethics and innovation. This study does not aim to include all possible terms in the field as it is challenging to have all potential terms in one study (Darko and Chan, 2016). Future research may consider broad terms for improved results. The "document type" was restricted to "article and review" as used in previous studies (Merigó and Yang, 2017; Jayantha and Oladinrin, 2019). The rationale for the restriction is that journal articles constitute the most influential and reliable study (Santos *et al.*, 2017) and have been rated as "certified knowledge" (Ramos-Rodríguez and Ruíz-Navarro, 2004) for science mapping purposes. We used only literature published in English for the collection, which might have resulted in the omission of some interesting studies. We acknowledge that ethics and innovation are general topics cutting across several disciplines in the literature; hence, we search for the theme "construction" within the search results in the WoS. Despite the search restrictions, non-construction journals still emerged and were subsequently excluded from the results except for the journal of business ethics because of its direct relevance in the study. We included all the journals listed in the Association of Researchers in Construction

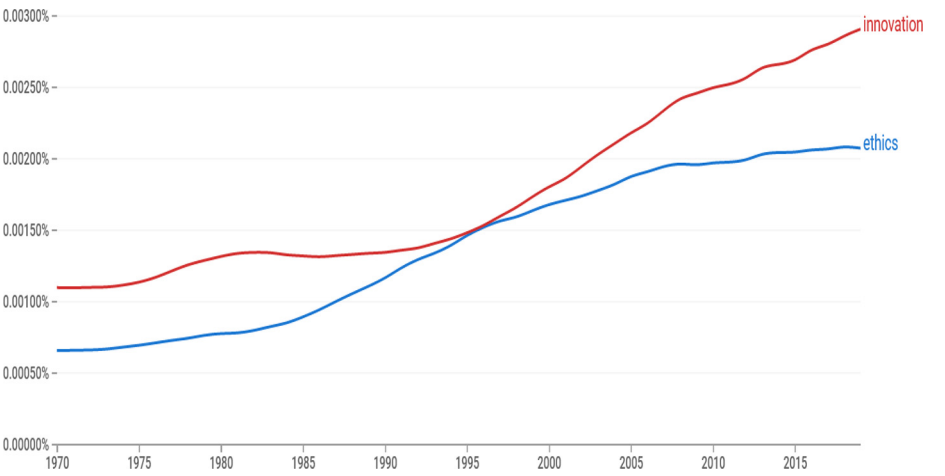

Figure 1.
Frequency of the terms "ethics" and "innovation"

Management (ARCOM) database and other construction-related journals that have published ten papers and above in this research domain. As of January 3rd, 2022, 5722 publications that treated ethics and innovation separately and 64 publications that combined both terms were found and were saved in "plain text" with "full record and cited references" of WoS. Therefore, a total of 5786 publications form a dataset for this study.

Mapping tool selection

The VOSviewer scientific mapping system was employed in this study to conduct a quantitative bibliometric analysis of the literature collected from the WoS database (van Eck and Waltman, 2010). Previous studies utilised bibliometric analysis to map the prevalence of related topics in search engines and areas that had received little academic attention (He *et al.*, 2017; Klarin, 2019). VOSviewer tools (Van Eck and Waltman, 2013) were used to analyse the bibliometric of the selected relevant articles.

VOSviewer became popular in the Scientometrics community and in other fields where scientific maps are utilised due to its simplicity of use and numerous features (including particular clustering and natural language processing algorithms) (Orduña-Malea and Costas, 2021). Unlike other computer tools used for bibliometric mapping, VOSviewer places a premium on graphical representation (van Eck and Waltman, 2010). The use of VOSviewer as a bibliometric tool to systematically analyse the literature provides several benefits, including a comprehensive literature analysis that allows us to conduct unprecedented scope investigations (Markoulli *et al.*, 2017), a number of tools for extracting reliable data from a series of units of analysis (Cobo *et al.*, 2011), and a transparent set of results offered with a reproducible rigorous process. VOSviewer bibliometric mapping software was applied to create a network visualisation of the most common terms used in the topics selected and the link between ethics and innovation in construction.

Analysis and results

This section presents the analysis of data using VOSviewer and results, including visualisation and interpretation. The results of each analysis are presented in tables for quicker understanding and then illustrated in figures for visualisation purposes.

Co-authorship

We performed a co-authorship analysis using the VOSviewer software to identify influential authors, active institutions, and countries and examine their association.

Author productivity. Using the indicator of co-authorship, the author productivity section aims to display the authors with higher productivity and collaboration. It aided us in identifying the most influential authors and ranking them based on documents and citations. 14754 authors were responsible for the publication of 3715 documents extracted, out of which only 81 authors have published ten articles or more. Of the 14754 authors spotted on VOSviewer, we focused on the top 10 prevailing authors with documents as well as citations. Table 1 shows the 10 most productive researchers in knowledge about ethics and innovation in construction between 1995 and 2021. The most productive author is Heng Li of the Hong Kong Polytechnic University, with 49 articles published during the period analysed. Heng ranked third in terms of citations received in this research domain. Weisheng Lu of the University of Hong Kong, ranked second with a total of 38 research articles. This is followed by Albert P.C. Chan also of the Hong Kong Polytechnic University, with 34 publications.

Interestingly, Wang, Xiangyu of Curtin University, who ranked fifth having registered 28 articles, ranked first in terms of number of citations. We found out that most of the

productive authors are biased towards research in innovation (such as BIM, smart construction technology, concept of smart cities, digitalization in construction, real-time employee or workflow monitoring, artificial intelligence technology, sensor-based technology and various Internet of Things) with limited or no focus on related ethical issues. There is also no significant collaboration with researchers with an ethics background.

Figure 2 depicts a collaboration map among the key authors who have published on ethics and innovation in construction based on the co-authorship analysis. The colours represent working groups, and the size of the circle depicts the number of articles published by each author. The network has a lot of dispersion, which could help the research area expand quickly. Among the most productive authors, only Heng Li seems to have the most stable international research collaboration. The author has research networks covering five different clusters of researchers in this research area extending to China, USA and Australia.

Organisations. Table 2 lists the ten organisations that have produced the most academic papers in the areas of research. It is seen in the classification that most of the top productive institutions are of Asian origin. The Hong Kong Polytechnic University is the most productive institution with 258 articles published in the period analysed. The University of Hong Kong has 122 published papers, closely followed by Tongji University with 105

Author	Document	Rank	Author	Citation	Rank
Li, Heng	49	1	Wang, Xiangyu	2,170	1
Lu, Weisheng	38	2	Teizer, Jochen	2,103	2
Chan, Albert P.C.	34	3	Li, Heng	1,978	3
Skitmore, Martin	33	4	Chan, Albert P.C.	1,314	4
Wang, Xiangyu	28	5	Lu, Weisheng	1,103	5
Hosseini, M. Reza	27	6	Skitmore, Martin	1,059	6
Teizer, Jochen	27	6	Cheng Jack C.P.	973	7
Pan, Wei	25	8	Haas, Carl T.	969	8
Cheng Jack C.P.	24	9	Akinci, Burcu	906	9
Zuo, Jian	23	10	Wu, Peng	825	10

Table 1.
Prominent authors by documents and citations

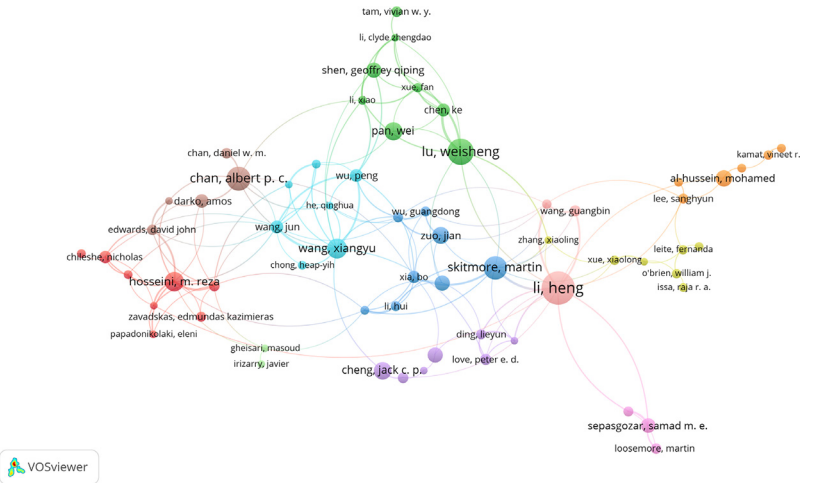

Figure 2.
The network of cooperation, based on the co-authorship of the principal authors

articles. These three institutions are from the same region and have more than 100 publications each.

The map generated by the VOSviewer software (Figure 3) shows the prominent universities that published articles on the topics and the cooperation between the institutions. The Hong Kong Polytechnic University stands out among others. It could be evidence that the institution was more focussed on studying the contexts of construction innovation and ethics parameters.

Geographical analysis of publications. Country co-authorship analysis was conducted to reflect the degree of communication between countries and the influential countries in this field. Table 3 shows the top 10 countries in terms of numbers of publications and citations

Organisations	No. of publications	Citations
The Hong Kong Polytechnic University	258	9,590
University of Hong Kong	122	3,339
Tongji University	105	2,355
Georgia Institute of Technology	73	4,188
Deakin University	72	1,913
Chongqing University	71	2,993
Queensland University of Technology	71	1,587
Tsinghua University	70	1,959
National University of Singapore	70	1,926
RMIT	69	1,511
The Hong Kong Polytechnic University	258	1,265

Table 2.
Top 10 universities in the data set by number of documents published

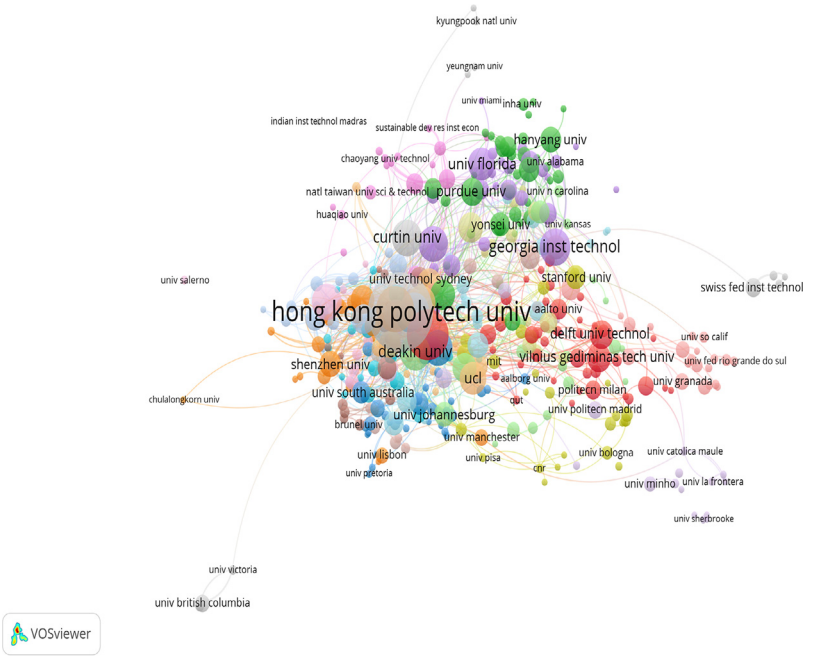

Figure 3.
Map of institutional cooperation in the research field

during the period analysed. Peoples Republic of China is the country with the highest number of articles (1,518), followed by the USA (1,035), England (610) takes the third rank and closely followed by England (394) in the fourth position. The origin is much more dispersed, cutting across European, Asian, American and Oceanic regions.

Figure 4 presents the country co-authorship network of innovation and ethics related publications with seven clusters. Figure 4 has a variety of colours, indicating the diversity of research topics. The large nodes represent the influential countries. The links between nodes represent the cooperative relationships among countries. The distance between the nodes and the thickness of the links represent the level of cooperation among countries. The red cluster is the one with the most significant number of countries (26) and is led by Italy. It is followed by the green cluster, with 12 countries, including Spain, France and Argentina, then the deep blue cluster, with a total of eight countries, which China leads. The USA is included in the purple cluster with seven countries, including Canada, Turkey and Qatar, whereas England is in the smallest cluster in orange colour, with a total of five countries, including South Africa, Ghana and Nigeria. The highest link strength (118) is between Australia and China, followed by the USA and China being 79, England and China being 56, while the link strength between China and Singapore is 20. It implies that physical

Table 3.
Ranking of the most productive countries in the number of articles

Country by documents	Documents	Rank	Country by citation	Citations	Rank
Peoples Republic of China	1518	1	Peoples Republic of China	29,109	1
USA	1035	2	USA	28,459	2
England	610	3	England	16,224	3
Australia	603	4	Australia	15,495	4
South Korea	307	5	South Korea	6,442	5
Italy	255	6	Canada	5,964	6
Canada	254	7	Italy	5,250	7
Spain	243	8	Spain	4,811	8
The Netherlands	144	9	The Netherlands	3,491	9
Germany	136	10	Germany	3,422	10

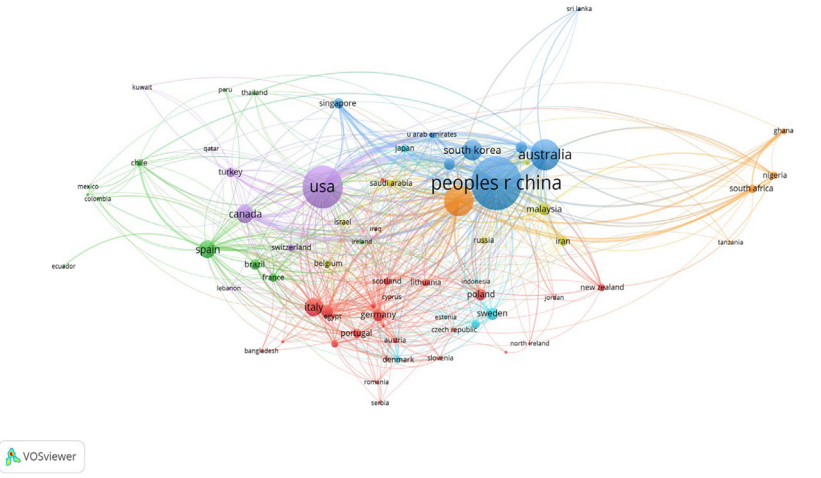

Figure 4.
International cooperation, based on the co-authorship between countries

proximity is not the most critical aspect influencing cooperative relationships. Countries with a developing economy were rare and irregular in the literature because they lacked sufficient resources for innovation (Nobanee *et al.*, 2021).

Co-occurrence

Previous studies have used quantitative calculations based on the co-occurrence frequency of keywords that expressed the research content and clustered the research focus based on the strength of the correlation between the keywords to observe the evolution track of subject knowledge (Callon *et al.*, 1991; Law and Whittaker, 1992). In this section, we analysed the distribution of keywords to explore the contents. The keywords examined here are those used by writers in their publications' titles, abstracts, and keywords sections. The frequency with which a term appears alongside other terms is referred to as co-occurrence. Keyword utilisation reveals a pattern in previous publications and predicts future areas that may acquire prominence, which may aid researchers in identifying topics that have yet to be studied. Keywords co-occurrence analysis of a study area can effectively represent research hotspots, offering additional support for scientific research (Li *et al.*, 2016). The keywords in construction ethics and innovation cover a wide range of topics. However, the top keywords in ethics and innovation articles, the keywords co-occurrence network, the keywords density visualisation, and the keywords timeline view would all be shown. The top 10 keywords with their frequencies and total link strengths are shown in Table 4. The keyword "construction" has the highest frequency of (1,069), followed by "management" (796), "performance" (728), "innovation" (635)and "design" (554).

The 5,786 documents contain 19,508 keywords, and the minimum occurrences of keywords were set to 5. Only 1,602 keywords meet the set threshold, and these were visualised, as shown in Figure 5, with 49056 links and total link strength of 105329. The weights of the nodes are represented by the size of the nodes and words. The weight is proportional to the size of the node and term. The strength of a relationship between two nodes is reflected in the distance between them. A shorter length indicates a closer relationship. A line connecting two keywords suggests that they have appeared together. The nodes with the same colour belong to a cluster. VOSviewer divided the keywords of ethics and innovation-related publications into seven clusters. Cluster 1 is red colour (performance, behaviour, concrete, durability), Cluster 2 is green colour (construction, management, innovation, ethics etc.), Cluster 3 is blue colour (technology, model, system, BIM, safety, tracking), Cluster 4 is yellow colour (design, sustainability, embodied energy, efficiency). The node, "innovation", with total links of 687, has higher link strength with

Keyword	Occurrences	Total link strength
Construction	1,069	6,786
Management	796	5,818
Performance	728	5,063
Innovation	635	4,574
Design	554	3,893
Technology	522	3,496
Model	448	2,913
Sustainability	384	2,655
System	376	2,542
BIM	357	2,470
Framework	297	2,406

Table 4. Co-Occurrence of authors' keywords

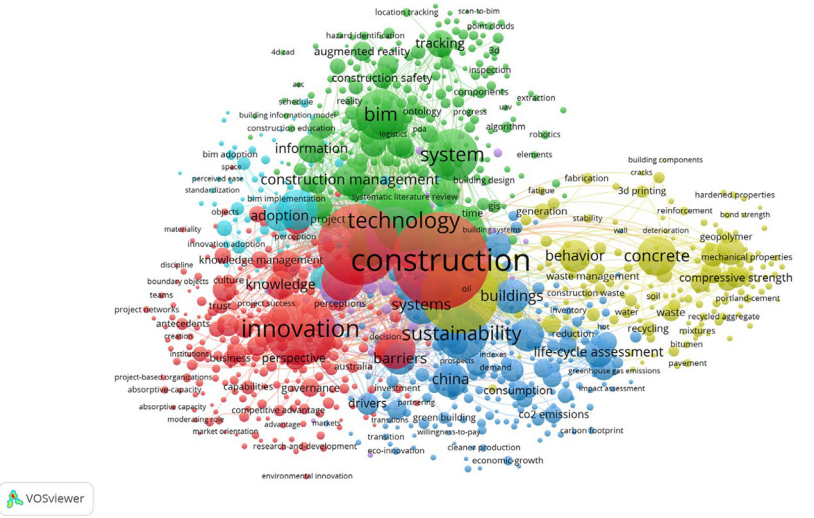

Figure 5.
Cluster visualization map for co-occurring keywords

"construction" (172), "management" (155), "performance" (127), "design" (82) and "implementation" (68), implying close integration of innovation and these research topics. The node "ethics" has a total link of 177, but none of the link strengths is greater than 10, with four of the associating nodes having above five-link strength, including construction, management, organisations, and discourse. There is no significant link between "ethics" and other themes, which is a concern for further research. This analysis reflects the knowledge evolution of ethics and innovation research domains.

Figure 6 shows a VOSviewer-generated overlay visualisation network with the colour of the keywords indicating the trend of the research theme of the documents analysed.

The generated network and links show that in 2015, there was an increase in publications on topics such as ethics, business ethics, public policy, R&D, information technology and radio-frequency identification. This finding implies that during 2015

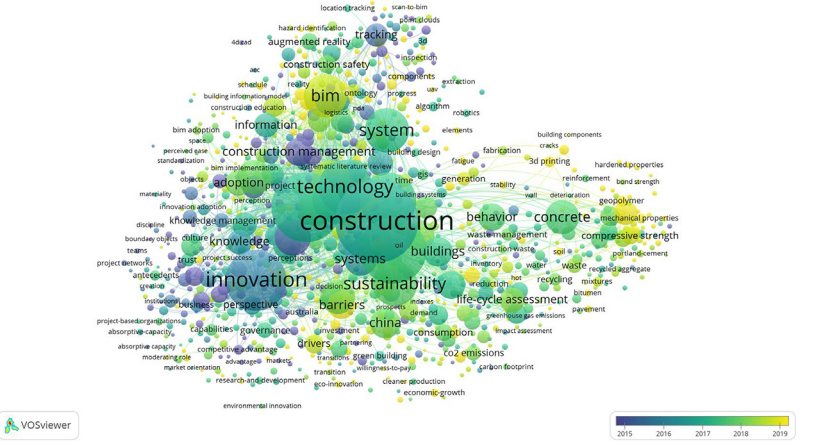

Figure 6.
Overlaying visualisation network of research topics

numerous studies focussed on ethics and various technology tools to manage construction activities and processes. In 2016, keywords with strong co-occurrences were identified as sustainability, innovation, governance and construction safety. In 2018, researchers focussed on performance, leadership, BIM, tracking system, sensor-based technology, behaviour and organisations. This figure shows that the hottest topics in the literature are digital fabrication, 3D printing, building information modelling, extrusion, barriers, adoption, implementation, construction safety and accelerated carbonation. Future research can potentially undergo these areas and the most commonly used keywords provided earlier, such as tracking system and sustainability. For instance, sustainability is a human devised concept, and the human being causes imbalances in nature; thus, future research should consider the ethical dimension of sustainability.

Brief discussion

This review used science mapping to uncover influential authors, institutions, articles and keywords on ethics and innovation in construction. The analysis reveals the knowledge base and enhances understanding of the intellectual structure of the research field. Innovation is a fast-evolving research area attracting a lot of multidisciplinary interest, including ethical challenges that arise with the deployment of new technology (Ekeskär, 2019). The concept of "ethical innovation" is relatively new. The word implies that, in recent decades, innovation has been less than responsible; the detrimental impact of inventions on persons, society and eco-systems has been largely ignored in favour of economic development and wealth creation (Blok and Lemmens, 2015). Surprisingly, the literature fails to comprehensively illustrate the link between ethics and various types of innovation holistically for both industrialised and emerging countries. The USA, perceived to be the world leader in both technological innovation and ethics, has published the most articles in these areas. Their influence in these fields may be related to technological, economic and academic advantages (Xie *et al.*, 2020). The trend of innovation in China also calls for ethical concern. The Hong Kong Polytechnic University, the University of Hong Kong and Tongji University have published the most significant number of articles among institutions and had the most citations of their articles, reflecting the importance and leading role of these three institutions in ethics and innovation research.

The findings revealed a need to explore ethical issues concerning the adoption and implementation of modern construction methods such as digital fabrication, building information modelling, 3D printing, and innovative approach to safety management in construction, being the main research areas in recent times. The keyword co-occurrence map also recognises the importance of ethical innovation to reach sustainable development in construction. Therefore, ethical innovation plays a significant role in the direction of sustainable development (Wesarat *et al.*, 2017). Another stream of research addressing ethical decision-making in innovative development in construction follows the assumption that innovators may be more likely to make unethical decisions as behaviour in organisations appears to be attracting researchers attention in recent times. Decisions that are inconsistent with societal moral norms may have a detrimental influence on the company's profitability and may also frighten stakeholders or even lead to personal issues. Researchers attempting to solve this may concentrate on organisational motives, as focusing on motives behind innovation may increase their moral apathy (Vallaster *et al.*, 2019).

Implications of the study

The recent global challenges posed by the COVID-19 outbreak that resulted in the almost universal cessation of construction activities in many countries has brought

about a compelling need for innovation in the construction industry. The opportunity exists to expand research into innovations that will prevent the exposure of all stakeholders in the industry to potential infection of not only the current COVID-19, but also increase the preparedness of the industry. Given that the industry is still labour-intensive by nature, there are ethical concerns regarding innovative development in construction due to behavioural issues. The effectiveness of social separation between employees on site of around 2 m poses issues to the way construction operations are usually carried out. Thus, innovative ways of working are imperative. As future studies concentrate on investigating basic construction functions and creating technology that can carry them out either without the physical involvement of construction workers or at a distance from other employees, ethical dimensions of such development should not be undermined. When promoting off-site and remote work as well as using virtual communication platforms, cybersecurity issues will require particular ethical attention. Construction codes of conduct and ethical frameworks will need to be updated to accommodate new contractual, working, and labour employment circumstances that include requirements for the use of new technology and training to utilise them. Identifying and comprehending areas of innovation in construction is critical for practitioners because of the accompanying ethical solutions that should be adopted when confronted with an ethical dilemma. This study helps portray a theoretical background of ethics and innovation research and effectively enables future scholars to focus on their studies. The key contributions of this study include statistical patterns analysis and presenting an instructive overview of the different contexts and intersections between ethics and innovation in the construction context – at a time when the sector is expected to face change and accelerations.

Conclusion

The growth in construction innovation that poses new problems and opens new opportunities means that ethics is becoming increasingly important in the construction industry. This study uses some bibliometric indicators to provide some insightful findings, mainly using the WoS database. The number of citations and publications was used to give a general overview of the most productive authors, universities, countries, and key trends. In addition, we used VOSviewer tools to create a graphical representation of the bibliometric data. For so doing, the study considered the co-authorship of authors, countries and universities, and co-occurrence of keywords. Bibliometric analysis is a vital method for gaining a comprehensive understanding of a specific field of study. This analysis shows that Heng Li and Weisheng Lu are the most productive authors with 49 and 38 publications. The Hong Kong Polytechnic University, followed by the University of Hong Kong, is the most productive in terms of the contributing organisations. Several countries across the globe have contributed significantly to the progress of innovation and ethics in construction research; the detailed analysis of countries enabled us to find that the Peoples Republic of China and the USA, respectively, are the top two contributing countries. Also, the visualisation of the co-occurrence of the keywords helped us discover the pattern of knowledge diffusion among the inter-connected communities in ethics and innovation research domains. The most commonly used keywords are innovative design for enhanced performance in construction (Table 4). There is a need for further research on the ethical dimension of construction innovations such as ethics and innovative safety, ethics and sustainability.

To conclude, ethical dimensions of innovation in the construction industry seem to be overlooked. The results revealed a limited intellectual exchange and lack of cohesion characterising the two concepts (ethics and innovation), resulting in a situation whereby innovation-related researchers tend to follow personal trajectories in isolation from ethics-related researchers in the construction field. Innovation is not only technical or economically beneficial but also ethical and socially beneficial. Jobs can be created or destroyed as a result of advancements in technology. The word "new" is not necessarily synonymous with good, but it may mean more effectiveness in some situations. Being effective does not exclude the chances of devastating effects on people. Although it is not always easy, responsible innovation is critical because we live in a dynamic age marked by disruption, requiring careful thought, especially in light of the positive and negative repercussions. While specific outcomes are not easy to predict, it is essential to make an effort by critically following each invention and analysing the results to humanise innovation. Innovation presents problems and opportunities for those who research corporate ethics because it poses new circumstances and uncharted waters, such as changes in the ethical behaviour of construction employees as a result of technology innovation. While the bibliometric study shows that construction innovation research is becoming a popular field of research, much of the knowledge created is solely technological. As a result, it lacks the social intelligence, cultural artefacts, and principles necessary to guide innovative development, including risk management and individual rights. To address the challenge posed by this situation, members of the scientific community investigating construction ethics must significantly enhance their intellectual interaction. However, a thorough interpretation of the phenomena is needed for ethical reflection, which calls for a severe interdisciplinary investigation. Hence, more collaborative research is crucial to humanise innovation and expand moral imagination for innovation that focuses on people and their needs. Researchers interested in construction ethics and innovation studies can find these analyses helpful in identifying trends and related issues. Furthermore, based on the current direction of the field of study, this paper includes a specific research agenda and recommendations to be developed in the future.

Like any other review paper, this study is also not free of limitations. The first limitation of the study is derived from the selected articles and reviews, which are mainly construction and ethics-related. Since innovation and ethics cut across several fields of study, comprehensive inclusion of journals from other fields will produce different results. As a result, extreme caution should be exercised in extrapolating the conclusions of this study to the broad subject of ethics and innovation. Another limitation is the research period (1995–2021); the results may vary in the future as we anticipate the changing nature of innovation will introduce new subjects, concepts and approaches that will significantly alter the findings of this study. Finally, because the study is based on data acquired from the WoS database, the limitations of the WoS database may apply to this study as well. As a result, future analyses should be based on data from multiple sources such as Scopus. Furthermore, such a researcher may use Altmetrics, a recent and systematic bibliometric tool to analyse research outputs' academic and social impacts. This can be used in conjunction with scientometric analysis further to explain the field's dynamics and new research areas. However, the bibliometric data analysis in this study contributes to the literature by giving a comprehensive and extensive review of key publications in construction ethics and innovation research.

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