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# GLOBAL TRENDS OF THE RESEARCH ON COVID-19 RISKS EFFECT IN SUSTAINABLE FACILITY MANAGEMENT FIELDS: A BIBLIOMETRIC ANALYSIS

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## ABSTRACT

This study used bibliometric analysis to investigate global research trends regarding the effect of COVID-19 risks in sustainable facility management fields. Between 2019 and 2021, the Scopus database published 208 studies regarding the effect of COVID-19 risks on sustainable facility control fields. VOSviewer software was used to analyse the co-occurrence of all keywords, and Biblioshiny software allowed getting the most relevant affiliation using the three-field plot. The results show the contribution by authors from 51 countries, and 73 keywords were identified and organised into six clusters, such as the effect of COVID-19 risks on human health, supply chain in construction projects and industry, disaster risk management in a changing climate, sustainable supply chain benchmarking, facility management and quality control, and, finally, sensitivity analysis & decision-making.

## KEY WORDS

**sustainable, facility management, benchmarking, risk management, COVID-19, bibliometric analysis**

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## INTRODUCTION

Monitoring and controlling sustainable projects through facility management benchmarking concepts could reduce many risks and enable corrective actions to be taken promptly (Elmualim et al., 2012). Creat-

ing sustainable environments is an issue addressed by the Facility Management (FM) discipline in a multi-disciplinary and integrative way (Becker, 1990; Alexander, 2003). FM plays an essential role in creating a sustainable environment, as it is a practice that ensures effective operational management of buildings (Aaltonen et al., 2013; Shah, 2007). Therefore,

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FM can continuously improve building performance through low or no-cost maintenance, retrofits, and operation strategies combined with proactive operational control and maintenance (Finch & Zhang, 2013).

Concerning the built environment, FM considers the design, maintenance, improvement, and adaptation of buildings and assets over time in the most cost-effective manner (BIFM, 2012). The built environment has several types of residential and commercial buildings, including healthcare, industrial, governmental, educational, agricultural, religious, etc. FM can measure customer satisfaction to support its services, reflecting the requirements related to performance satisfaction and productivity (Alexander, 2003). FM has been a leader in maintaining the facilities' environmental sustainability performance (Shah, 2007). According to Elmualim et al. (2012), facility managers align their practices with social, environmental, and economic ideas of sustainability. However, they are bound by time, the lack of basic information to execute sustainability policies, and the lack of senior management commitment to the sustainability agenda (Elmualim et al., 2012).

Altonen et al. (2013) asserted that sustainable facility management services are given a key role in reducing a company's overall environmental impact through their direct and indirect effects on building environmental performance measures and on readily available data required for green management. Therefore, FM is essential to the planning, construction, and operation of sustainable facilities that are resource-efficient in terms of energy and natural resources (Shah, 2007). As mentioned earlier, the contribution of FM is of paramount importance to the planning and operation of the most resource-efficient and maintainable sustainable buildings (Aaltonen et al., 2013).

Facilities Management Benchmarking (FMB) allows organisations to compare aspects of performance, identify differences, find alternative approaches, evaluate improvement opportunities, implement change, and monitor results. Benchmarking is referred to as "the art of discovering, in an exceedingly completely legal and ideal way, how others do something better than you" (Meng & Minogue, 2011).

The Construction Industry Institute (CII) defined benchmarking as a scientific process of measuring performance against recognised leaders to work out best practices that result in superior performance when adapted and utilised (CII, 1995). Benchmark-

ing could be a multistep process that enables a company to check aspects of performance, identify differences, explore alternative methods, evaluate opportunities for improvement, implement change, and monitor results. Benchmarking was first introduced in the United States of America in the 1990s (Tasopoulou & Tsiotras, 2017) to check the functions and operations of a corporation with those of another organisation to get an external standard. The external criterion can assess the quality and cost of internal processes and explore opportunities for improvement (Alstete, 1995).

Benchmarking concentrates on internal or external measurement (Poister, 2003). In selecting the external measurement, the company either makes direct rapprochement with competitors within the industry or measures other organisations outside its immediate purview. The standard benchmarks for facilities are flexibility, efficient use of space, maintenance management, a secure environment, and value for money. Internally, facility management benchmarking should emphasise business performance or business-related issues (Atkin & Brooks, 2000). Petersen et al. (1996) identified five distinct stages: planning, research, observation, analysis and adaptation.

The successful implementation of normative benchmarking is reflected in numerous publications coping with the concept, application, and limitations (Macneil, 1994; McNair, 1992). Since the 1990s, there has been significant interest in benchmarking in manufacturing, construction, and other service industries. In 1993, the United States Army Corps of Engineers (USACE) conducted a study to assess project delivery for a federally funded environmental restoration programme using standards and metrics. The researchers selected specific typical performance metrics (e.g., cost growth, schedule growth, planning phase cost factor, design phase cost factor) from those developed by the Building Industry Institute. The study assessed the flexibility of the environmental management programme to implement projects. Additionally, USACE researchers self-evaluated whether the program design goals were achieved. They also addressed customer concerns about O&M costs by calculating the particular cost divided by the estimated cost. USACE researchers found that Corps has improved the delivery of environmental management projects (EMP) because cost and schedule growth trends have shown a consistent decline (Siddiqi, 2004). Konchar and Sanvido (1998) compared cost, schedule, and quality measures on a sample of

351 building construction projects delivered in line with the three most often used project delivery methods: construction at risk, design-build (DB), and design-bid-build (DBB). The researchers concluded that design-build (DB) project delivery provides significant advantages in cost and schedule. It also produced equally and sometimes more desirable quality performance than at-risk construction management.

In 2020, the COVID-19 pandemic struck the entire world. It became a public health emergency that represented a source of professional concern and a high risk to several sectors, including the construction industry. The American Industrial Hygiene Association (AIHA; 2020) has classified COVID-19 as a brand-new construction hazard. Similarly, the European Union Commission as a Group 3 biohazard known to infect humans, which is additionally an occupational health and safety concern (Franklin et al., 2020), has classified COVID-19. According to AIHA (2020), the risk of contracting COVID-19 infection in the construction sector increased rapidly due to the nature of construction work that requires the proximity of workers and sharing of ordinary workplaces, such as elevators, lunch break areas, and sanitation complexes.

Chigara and Moyo (2021) explored factors influencing the delivery of optimum health and safety on construction projects during the COVID-19 pandemic in Zimbabwe. The researchers used factor analysis to reveal nine factors: change and innovation, monitoring and enforcement, production, access to health information and services, on-site facilities' management associated with well-being, risk assessment and mitigation, job security, financing, cost, etc. The findings highlighted the need for social dialogue among construction stakeholders to support initiatives that would enhance the delivery of health and safety in construction projects to workers during the pandemic.

Amoah and Simpeh (2020) used a qualitative study of construction professionals in facilities in South Africa to identify challenges to implementing COVID-19 H&S measures. The main factors that have influenced the implementation of COVID-19 safety measures were spacing requirements, low-risk perception of COVID-19, the supply of inaccurate information, insufficient knowledge of COVID-19, and the supply of poor Personal Protective Equipment (PPE). Zheng et al. (2020) demonstrated that the lack of knowledge and non-compliance with certain COVID-19 safety practices contributed to the spread of COVID-19 in the construction industry in

China. In the USA, Hatoum et al. (2021) analysed worker complaints data from OSHA and concluded that the main factors were the inadequate implementation of public and specific COVID-19 health and safety provisions and inadequate (PPE) for workers.

COVID-19 made some terminology more common in everyday life, such as social distancing, self-isolation, and quarantine, and the construction industry is no exception. The lockdown for the COVID-19 pandemic caused business disruptions all over the world, primarily in the construction asset procurement and facility management sectors (Ogunnusi et al., 2020). As these serious and unexpected situations may recur in the future, it is important to know how they can affect sustainable facility management. For this purpose, it is necessary to understand the scientific contributions to sustainability and risk factors in facility management projects during the COVID-19 pandemic.

Therefore, the objective of the article is to investigate the contributions to benchmarking facility management to minimise the risks of the spread of the Covid-19 pandemic, highlighting its effects on sustainability. The study relied on expanding knowledge from previous studies by adopting bibliometric analysis of Scopus research data during the period of the coronavirus pandemic.

This article has five sections. A brief introduction is followed by a literature review on bibliometric research, then the research methodology is described, and the results are presented and discussed, describing the evolution of the field and the trends of the effect of COVID-19 risks in sustainable facility management. The last section offers conclusions, the study limitations and proposals for further research.

## 1. LITERATURE REVIEW ON BIBLIOMETRIC RESEARCH REGARDING COVID-19

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Despite the review articles not introducing new models or methodologies, these make a significant contribution by providing a brief, up-to-date overview of the field's evolution (Amin et al., 2019).

The bibliometric approach is useful for developing a summary of a research field because it identifies the most important trends in the field by analysing a variety of bibliometric indicators, including the number of publications and citations, the most influential countries, the most relevant authors, the most prominent institutions supporting research, and the

citations of papers in major articles (Martinez-López et al., 2020). Corsi et al. (2020) suggested that bibliometrics are a collection of methods to study or measure texts and information about all types of written communication, their authors, and publishing styles. Bibliometric is an open-source tool for quantitative research in scientific measurements and bibliometric developed by Massimo Aria and Corrado Cuccurullo. Because of open software, it is also easy to get help from the user community, which mainly consists of prominent statisticians. Therefore, bibliometric is flexible, quickly upgraded, and combined with other R statistical packages.

After the pandemic, several studies have been developed to ascertain the impact of COVID-19 on the development of many scientific fields, including facilities management benchmarking and risk management. Zhang et al. (2019) used a bibliometric-qualitative analysis to investigate 724 academic journal papers on FM issued between 1995 and 2018. Some of the latest advancements and emergent trends were identified based on knowledge maps in FM, including changing circumstances, enhancing information technology, all-around facility manager, strategic performance management, sustainable FM, and innovative FM practice.

Verma & Gustafsson (2020) analysed COVID-19 in the business management domain using Biblioshiny software and identified four main research themes: COVID-19 and business, COVID-19 and technology, COVID-19 and supply chain management, and COVID-19 and the service industry. Supply Chain Management and COVID-19 were also the focus of the research of the bibliometric analysis developed by Sombultawee et al. (2022). They found 257 papers published in 2020 and 2021 and identified four thematic clusters comprised of the impact of the COVID-19 pandemic on supply chains, the improvement of supply chain resilience for viability, technology and innovation for supply chain sustainability, and supply chain risk management in response to COVID-19. Within Cluster 4, one of the studied aspects was supply chain sustainability, i.e., the impacts caused by the COVID-19 pandemic as possible proposals to deal with COVID-19 disruptions.

Wang & Huang (2021) explored the publications in the Web of Science database related to the COVID-19 impact on sustainability by using bibliometrics techniques and the meta-analysis approach.

The results show that the research scope is extensive, covering many subjects but not in-depth. In addition, they show that the COVID-19 pandemic

has negatively affected the 17 Sustainable Development Goals (SDG), whereas the pandemic may also bring opportunities to develop actions on 14 out of 17 SDGs.

Nobanee et al. (2021) used a bibliometric method to collect literature on sustainability and risk factors and analyse the relevant literature. This bibliometric analysis has been developed to understand further the importance of sustainability for individuals, businesses, and the economy. Moreover, risk-related factors were examined to prevent a negative impact. The researchers applied the following keywords: sustainability practices, risk assessment, sustainable development, and environmental impacts. The researchers used the VOSviewer software to analyse and identify citations relevant to topics critical to sustainability and risk contexts from 1990 to 2020. The results showed 1 233 Scopus documents on sustainability and risk management practices during the analysis. On the other hand, the researchers highlighted six main clusters relating to ethical responsibilities and sustainability development, blockchain technology and risk reduction, social and supply chain sustainability, environmental impacts, safety engineering, risk identification, and optimisation of sustainability practices. The researchers concluded in their study that sustainability practices represent a high-quality performance in the work environment, while risks remain a challenge.

Appiah et al. (2022) developed a scientific map and conducted an in-depth analysis of the knowledge supplied by management professionals examining the influence of COVID-19 on business performance. Researchers looked for “COVID-19” and “Coronavirus” in combination with other keywords (“value”, “performance”, or “profitability”) in the Scopus database. They identified three main research clusters: foundational discussions and risk assessment, crisis and strategic management and performance outcomes and strategies. They identified some research gaps that could point to future lines of research. One of them is the lack of attention to the supply chain’s reactions under different pandemic plans, as different elements of the supply chain can influence the management during such a crisis as COVID-19 (Kryeziu et al., 2022).

Other bibliometric research on COVID-19 showed the importance of the sustainability concept for the post-COVID-19 period, as in the research of the management strategies and policies in hospitality and tourism (Khan, Nasir, & Saleem, 2021) and the human mobility behaviour (Benita, 2021). The

authors pointed out the importance of the operations and maintenance of vehicles and facilities as one of the sustainable actions to be included in post-COVID management.

## 2. METHODOLOGY

The methodology of this research is a bibliometric analysis. It was divided into two phases: first, a bibliometric performance analysis and second, the development of a visual mapping of the references within the facility management, risk management, and sustainability research field. Bibliometric analysis is considered one of the best techniques for mapping and analysing study production and the success of academics, authors, educational institutions, countries, and even journals in a specific subject area (Olawumi & Chan, 2018).

Many databases may map bibliographic data, including Dimensions Database, Google Scholar, Web of Science, and Scopus. The Scopus Database was utilised to analyse the influence of COVID-19 hazards on sustainable facility management. The authors conducted a bibliometric examination of the Scopus database journals, focusing on the Science Citation Index Expanded and the Social Sciences Citation Index. Scopus was chosen as the search database because it covers a larger number of publications and journals than other databases. In addition, Scopus contains a wealth of information, including the year of publication, authors, authors' affiliations, title, abstract, source journal, subject categories, and references.

The period for the bibliometric analysis was between 2019 and 2021, and the keywords used were "facility management", "risk management", "Covid-19", and "sustainability". Only articles published in English were selected. The researchers have exported the bibliographic details from the Scopus database in Bibliography Tex (.bib). Then, the R Studio was installed and loaded with the bibliometric R kit (version 3.0.3 published 28-Sep-2020). The R-package bibliometric (<https://www.bibliometrix.org/>) was used for overall analysis in scientometrics and bibliometrics. It is developed in R, uses efficient mathematical algorithms, and access to high-quality computational procedures, and is an optimised visual analytics software (Aria & Cuccurullo, 2017).

A total of 208 documents were selected and included in the second study phase. The development of graphical mapping of bibliometric material was

performed with the VOSviewer software (version 1.6.15, Nees Jan van Eck and Ludo Waltman, Melbourne, Leiden, The Netherlands). The researchers have used the VOSviewer software to visualise and map the co-occurrences for keywords, countries for co-authorships, most relevant affiliation, three fields plot, and factorial map in the exported data.

## 3. RESULTS AND DISCUSSION

### 3.1. PRIMARY INFORMATION

The primary information extracted from Scopus is shown in Table 1. The exported data consist of 208 documents from 2019 to 2021 (n=28 documents in 2020, n= 174 documents in 2021, and n= 5 documents in 2022) published in 124 different sources. The collected papers have 0.135 average years from publication and 5.058 average citations per article. All the sources have 32,552 references. The main information extracted from 208 sources can be found in Table 1.

### 3.2. KEYWORD ANALYSIS

The Scopus database was used to export bibliographic data for bibliometric analyses and mapping with the VOSviewer software. Co-occurrence analysis was used for all keywords to indicate the full strength between keywords and their occurrences. The clusters' volume indicates the strength and importance of words. In addition, the colours show the significance of clusters, and the curved lines indicate the links between words. A total of 3 302 text-data terms appeared, and 73 met the threshold of 5.

Fig. 1 illustrates the co-occurrence map of keywords. The map consists of six clusters; the strongest cluster refers to the COVID-19 keyword, which occurred 88 times and related to almost all other keywords, indicating the high impact and strong effect. The different keywords for each cluster were ranked in order of strength, i.e., sustainability, supply chain, decision-making and facility management.

#### CLUSTER 1: "THE EFFECT OF COVID-19 RISKS ON HUMAN HEALTH"

Table 2 presents keywords that belong to Cluster 1, including the number of occurrences of these keywords and the number of links they have. Cluster 1, "The effect of COVID-19 risks on human health", has

Tab. 1. General information exported from the Scopus database

DESCRIPTION	RESULTS
Main information about the data	
Time span	2019:2022
Sources (Journals, Books, etc.)	124
Documents	208
Average years from publication	0.135
Average citations per Document	5.058
Average citations per year per Document	
References	32552
Document Types	
Article	163
Book	5
Conference paper	2
Note	1
Review	37
Document contents	
Keywords Plus (ID)	1417
Author's Keywords (DE)	915
Authors	
Authors	923
Author Appearances	978
Authors of single-authored Documents	16
Authors of multi-authored Documents	907
Authors collaboration	
Single-authored documents	18
Documents per Author	0.225
Authors per Document	4.44
Co-Authors per Document	4.7
Collaboration Index	4.77

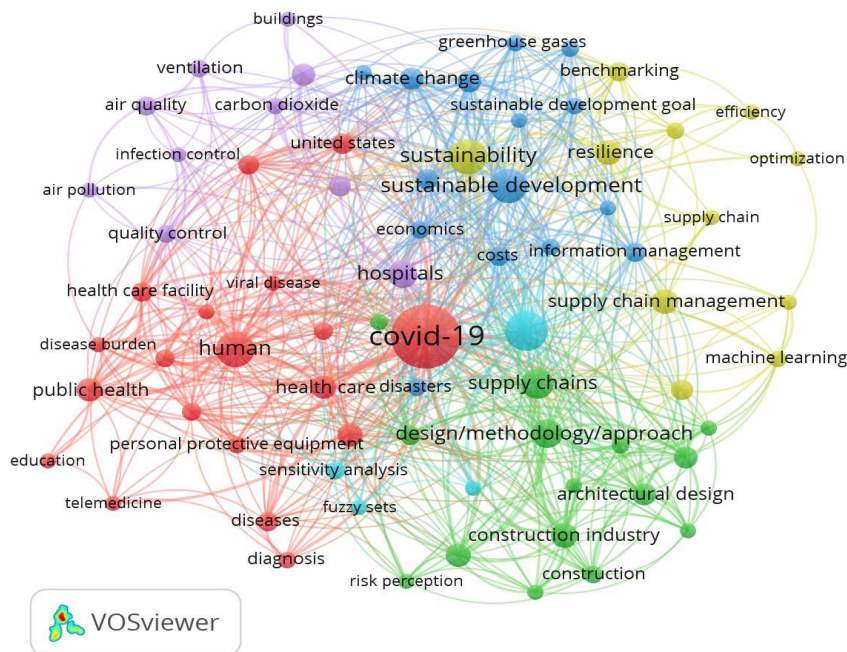


Fig. 1. Co-occurrence map for all keywords

Tab. 2. Keywords in Cluster 1 “The effect of COVID-19 risks on human health”

KEYWORDS (CLUSTER 1): THE EFFECT OF COVID-19 RISKS ON HUMAN HEALTH	LINKS	TOTAL LINKS STRENGTH	OCCURRENCES
Covid-19	62	199	88
Human	41	101	28
Health care	25	37	12
Public health	22	43	12
Risk assessment	27	42	12
Diseases	19	29	8
Health care facility	21	35	8
Waste management	24	41	8
Health risks	24	35	7
Epidemic	19	31	7
Developing countries	19	23	7
Personal protective equipment	18	25	6
Diagnosis	11	16	6
Viral disease	21	34	5
Water management	17	23	5
Disease burden	13	19	5
Telemedicine	10	13	5
Education	5	7	5

18 items. Keywords, such as health care and health risks, are the top themes in this research field.

COVID-19 is mostly spread through individual interaction, and the most successful tactics used by most authorities in afflicted nations to limit the disease have been social separation and lockdown (Pulano et al., 2020; Singh et al., 2020). The lockdown due to COVID-19 had both direct and indirect consequences: on the one hand, it had a significant economic, social, and cultural impact (Sarkar, Das, & Mukhopadhyay, 2021), while on the other, an improvement in air quality was observed in cities where these restrictions were implemented to contain the COVID-19 epidemic and achieve good human health (Baldasano, 2020).

For this reason, efforts may and should be taken to reduce the psychological and mental impacts of the COVID-19 epidemic. First, while it may appear appealing to re-deploy mental health professionals to other healthcare areas, this should be avoided. Such a change would almost surely reduce overall results and put those with mental illnesses at a disproportionate risk of physical and mental health deterioration. This group, if anything, currently needs greater attention (Cullen et al., 2020).

Second, we advocate for the provision of targeted psychological interventions in communities affected by COVID-19 with a focus on people at high risk of

psychological morbidity, increased awareness, and diagnosis of mental disorders (particularly in primary care and emergency departments), and improved access to psychological interventions (particularly those delivered online and via smartphone technologies). These measures can help reduce or prevent future psychiatric visits (Cullen et al., 2020).

#### CLUSTER 2: “SUPPLY CHAIN IN CONSTRUCTION PROJECT AND INDUSTRY”

Table 3 presents the keywords that belong to Cluster 2, including the number of occurrences of these keywords and the number of links they have. Cluster 2, “Supply chain in construction project and industry”, has 15 items. Keywords such as “project management” and “construction design methods” are the top themes in this research field.

Due to the obvious challenges of managing connections of a wide range of different businesses, supplying components, elements, the number of services, and interpersonal conflicts, supply chain implementation has obtained obstacles in the construction sector (Öztürk & Yildizbaşı, 2020; Ershadi et al., 2021).

Stone & Rahimifard (2018) stated that current manufacturing research in the supply chain, while useful, could indeed be readily applicable to a constrained context.

Tab. 3. Keywords in Cluster 2 "Supply chain in construction projects and industry"

KEYWORDS (CLUSTER 2): SUPPLY CHAIN IN CONSTRUCTION PROJECTS AND INDUSTRY	LINKS	TOTAL LINKS STRENGTH	OCCURRENCES
Supply chains	32	53	20
Design/methodology/approach	32	68	18
Construction industry	22	52	13
Surveys	21	39	12
Project management	23	44	11
Architectural design	22	36	10
Human resource management	27	40	8
Environment structured	18	27	7
Structured semi	18	23	6
Semi-structured interviews	19	31	6
Accident prevention	16	18	5
Automation	8	8	5
Building information modelling	15	22	5
Construction projects	16	26	5
Risk perception	14	18	5

Although an efficient supply chain is essential for lowering supply chain management construction costs, Prajogo, Mena & Nair (2017) observed that relatively little research has defined what the term "supply chain" implies in the context of the construction process. As a result, we chose to begin by defining the supply chain.

The construction industry has seen the launch of many Supply Chain Management (SCM) initiatives aimed at improving internal and external efficiency, reducing waste, and adding value across the entire supply chain, as well as attempting to eliminate adversarial inter-organisational purchaser-supplier relationships and fragmented business processes (Broft, Badi & Pryke, 2016).

Scholars have widely recognised the importance of SCM's contribution to improving company performance at various levels (strategic, tactical, and operational), thus shifting the focus from the internal structure to the external inter-organisational processes and relations, thereby enhancing strong feedback linkages and collective learning. However, SCM adoption in the construction sector has been fragmented and ineffective thus far (Neutzling et al., 2018).

SCM must be adequately defined, planned, structured, and carried out. As a result, the adopting organisations (primarily the general contractor and its subcontractors) must deal with managerial, organisational, relational, and technological issues that must be managed appropriately to effectively

apply SCM principles, models, and techniques and overcome barriers to construction SCM application (Broft, Badi & Pryke, 2016).

### CLUSTER 3: "DISASTER RISK MANAGEMENT IN A CHANGING CLIMATE"

Table 4 presents the keywords that belong to Cluster 3, including the number of occurrences of these keywords and the number of links they have. Cluster 3, "Disaster risk management in a changing climate", has 15 items. Keywords such as "sustainable development", "environmental climate change", "disaster", and "risk management" are the top themes in this research field.

Climate change mitigation, e.g., pollution reduction, has long been a component of sustainable developmental projects. Climatic change adaptation covers a set of actions aimed at mitigating risks and extracting advantages from climate extremes or changes. These actions are included in the concept of disaster risk reduction (Kelman, 2017; Szpilko & Ejdy, 2022).

There are two main components of Disaster Risk Management (DRM): Disaster Risk Reduction (DRR) and Disaster Management (DM). DRR is the concept and practice of reducing disaster risks through systematic efforts to analyse and manage the causal factors of disasters, including reduced exposure to hazards, lessened vulnerability of people and property, wise land and environment management,



Tab. 4. Keywords in Cluster 3 “Disaster risk management in a changing climate”

KEYWORDS (CLUSTER 3): DISASTER RISK MANAGEMENT IN A CHANGING CLIMATE	LINKS	TOTAL LINKS STRENGTH	OCCURRENCES
Sustainable development	40	86	25
Environmental impact	29	50	11
Climate change	28	43	11
Life cycle	29	50	9
Costs	25	34	8
Information management	21	25	8
Economics	24	38	7
Disasters	16	18	7
Investments	24	28	6
Greenhouse gases	20	28	6
Sustainable development goal	19	23	6
Planning	15	23	6
Risk management	22	24	5
Economic and social effects	20	26	5
Environment	18	20	5

and improved preparedness for adverse events. DM describes the development and application of policies, strategies, and practices that minimise vulnerabilities and disaster risks throughout a society, to avoid (prevent) or limit (mitigate and adapt to) the adverse impacts of hazards within the broad context of sustainable development (Begum et al., 2014).

Flood, weather, and drought risk reduction implemented for climate change adaptation is the same as disaster risk reduction implemented in general. Work to modify crops and extend growing seasons in response to climate change is strongly connected to prior efforts to use local knowledge to improve food security, especially for disaster risk reduction. As a result, to achieve sustainable development, a systematic relationship between Disaster Risk Reduction (DRR) and Climate Change Adaptation (CCA) is required (Birkmann & von Teichman, 2010).

Climate change has two actions: adaptation and mitigation, which are still divided despite having much in common. Climate change could be usefully placed within other sustainable development activities to avoid separating it from other activities and to accept all the overlaps and links because climate change adaptation is no different from disaster risk reduction, so it fits within that topic, which fits within sustainable development (Kelman, 2017).

#### CLUSTER 4: “SUSTAINABLE SUPPLY CHAIN BENCHMARKING”

Table 5 presents the keywords that belong to Cluster 4, including the number of occurrences of these keywords and the number of links they have. Cluster 4, “Sustainable supply chain benchmarking”, has 11 items. Keywords such as “sustainability” and “benchmarking” are the top themes in this research field.

Due to globalisation, market demand unpredictability, and current economic competitiveness, business organisations face a major challenge to their present supply chain. Simply focusing on internal efficiency and supply chain operations will not be enough for any company to acquire a competitive advantage in the market. To meet these mounting issues, sustainability performance has gained importance in recent years. Integrating sustainability principles into essential supply chain business processes allows organisations to establish a “competitive position” in the market in this modern era of a globally challenging environment.

Sustainable Supply Chain Management (SSCM) is viewed as the beginning of a new integrated environmental performance, social performance, and economic contribution — or what has been referred to as a combination of three pillars of sustainable development. Implementing SSCM techniques leads to enhanced material and energy efficiency, as well as

Tab. 5. Keywords in Cluster 4 “Sustainable supply chain benchmarking”

KEYWORDS (CLUSTER 4): SUSTAINABLE SUPPLY CHAIN BENCHMARKING	LINKS	TOTAL LINKS STRENGTH	OCCURRENCES
Sustainability	35	70	27
Supply chain management	15	20	14
Resilience	18	27	13
Artificial intelligence	14	17	9
Benchmarking	24	30	8
Data envelopment analysis	11	15	6
Machine learning	10	13	6
Forecasting	10	13	5
Efficiency	7	9	5
Supply chain	8	13	5
Optimisation	4	5	5

innovation, which improves an organisation’s economic performance and establishes a brand corporate reputation in the market (Ansari & Kant, 2017).

The benchmarking concept, which comes from the English word benchmark (“milestone”, “landmark”), is broadly practised in the US but has known international expansion in recent decades. The method consists of a systematic and permanent process of measuring and comparing the work processes of an organisation with those of another one to increase performance. It necessarily involves measurement and can be a learning method in an organisation about areas and the way that activity could be improved (Smallwood, 2019).

External standards that measure the quality of all aspects must and can help identify opportunities to improve SSCM activity and to identify “best practices” in their field of activity; however, in addition to standards-based measurements, there is a need for a desire and willingness to learn from the “good” or “bad” practices. To do this, strong trust-based communication with all local and central superordinate organisations is required to overcome internal reluctance to implement the necessary change. What and how other comparable companies have accomplished can be taken and incorporated into their organisational procedures.

Last but not least, any optimisation process carried out in any firm or company that resulted in redefining roles and activities following a new instructional design must support the valuable traditional aspects in the functioning of SSCM organisations and facilitate the creation of the necessary correlations with the innovative elements so benchmarking becomes a part of a total quality manage-

ment approach to facility management (standards, indicators, rules, etc.).

#### CLUSTER 5: “FACILITY MANAGEMENT AND QUALITY CONTROL”

Table 6 presents the keywords that belong to Cluster 5, including the number of occurrences of these keywords and the number of links they have. Cluster 5, “Facility management and quality control”, has 11 items. Keywords such as “energy utilisation”, “efficiency”, and “quality control” are the top themes in this research field.

Performance measurements can be analysed statistically, as in manufacturing, to assess whether the processes that a facility manager is executing to offer a service are under control. The advantage of Statistical Quality Control (SQC) is that it allows the facility manager to make sense of the outcomes produced in nearly any repeatable operation for which they are accountable (Montgomery, 2020).

The advantages of using SQC as a measuring tool are that it allows the FM to determine if a given process is under control and working consistently. An essential aspect of this is the capacity to explain to service users why action is not required every time a result deviates from the expectation. It enables the personnel to see how they are performing and to participate in the measurement and serves as a foundation for thinking about how to enhance the process and measuring how effectively a change is functioning (Dillon, 2021).

Sustainable Facilities Management (SFM) allows businesses to assess the quality of their resources and environmental management at their facilities. Furthermore, to maintain the operation of the built

Tab. 6. Keywords in Cluster 5 "Facility management and quality control"

KEYWORDS (CLUSTER 5): FACILITY MANAGEMENT AND QUALITY CONTROL	LINKS	TOTAL LINKS STRENGTH	OCCURRENCES
Hospitals	30	46	16
Energy utilisation	13	19	10
Energy efficiency	8	14	9
Air quality	12	17	8
Quality control	22	25	7
Ventilation	8	11	7
Carbon dioxide	19	23	6
Air pollution	7	10	5
Buildings	6	8	5
Infection control	9	11	5
Optimisation	4	5	5

environment, SFM necessitates the integration of many disciplines, including Mechanical, Electrical, Plumbing, and Fire Protection (MEPFP) (Ruan, Xie, & Jiang, 2017). The management and control of MEPFP systems in a facility are very important in building the operation and maintenance of SFM, especially in complex projects, such as hospitals, science labs, and technology parks, where the total investment of MEPFP systems on average can even reach 50 % of the total investment of such a project. SFM plays an important role in the development, maintenance, and management of these complex infrastructures, as it integrates people, location, and business to maximise the economic, environmental, and social advantages of sustainability.

#### CLUSTER 6: "SENSITIVITY ANALYSIS AND DECISION MAKING"

Table 7 presents the keywords that belong to Cluster 6, including the number of occurrences of these keywords and the number of links they have. Cluster 6, "Sensitivity analysis and decision making", has 3 items. Keywords such as "sensitivity analysis" and "decision-making" are the top themes in this research field.

Writers commonly fail to examine solutions using numerous Master Data Management (MDM) methodologies and perform sensitivity analysis (Payam & Fathipour, 2015). According to the

research, selecting the ideal MDM technique is a very complicated problem that, if not preceded by a sensitivity analysis of the solution, might result in a mistake decision if an MDM method that produces inconsistent results is selected (Pamučar, Božanić & Randelović, 2017). Therefore, models for evaluating the outcome consistency of multicriteria decision-making (MCDM) procedures are required. As a result, the model for sensitivity analysis (assessment of outcome consistency) of MCDM approaches must be defined. The prime objective of the sensitivity analysis of the technique proposed in this research is to choose such a technique that keeps the majority of priority areas during the modification of criteria weights and that wants to keep the rankings of alternative solutions in case of scales to measure change and shift in the way the requirements is constructed (Mukhametzyanov & Pamucar, 2018).

In MCDM, it is possible to see examples of examination of ranking outcomes acquired using various methodologies. It should be mentioned that the outcomes of this type of study are dependent on the observed technique choice and the features of the issues to which those methods are applied (Mukhametzyanov & Pamucar, 2018). As a result, various authors have reached various conclusions. In works in which structural rigidity and stability analysis of obtained solution is performed in MDM, analysis is frequently based on appropriate sensitivity analysis of results to changes in certain variables in

Tab. 7. Keywords in Cluster 6 "Sensitivity analysis and decision-making"

KEYWORDS (CLUSTER 6): SENSITIVITY ANALYSIS AND DECISION-MAKING	LINKS	TOTAL LINKS STRENGTH	OCCURRENCES
Decision-making	55	109	33
Sensitivity analysis	16	21	7
Multi-criteria decision making	9	13	5

the decision-making model, in addition to comparing with the result provided through other strategies and processes (Pamučar, Božanić & Randelović, 2017).

### 3.3. AFFILIATION

In Fig. 2, the most relevant institutions that support this research topic and the number of articles for

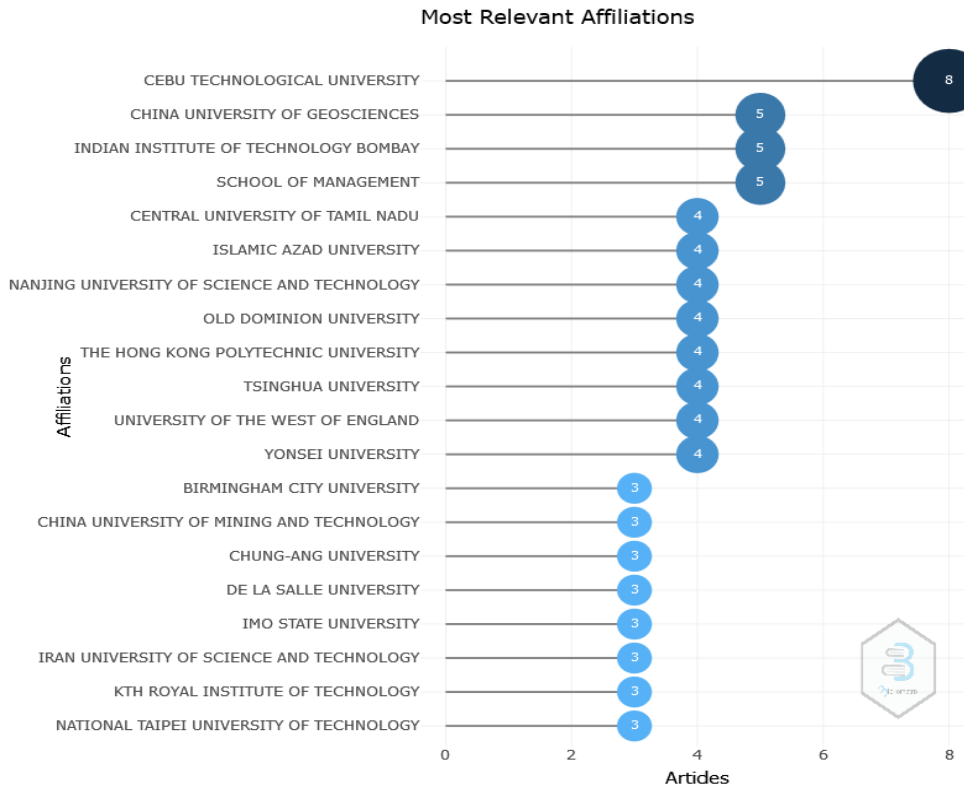


Fig. 2. Most relevant affiliations

each institution are represented. Cebu Technological University had the highest number of publications (eight documents) during the study period. There are 14 different universities publishing the topics of the research (84 % of all documents). The minimum number of publications was three documents for eight various institutions.

### 3.4. THREE-FIELDS PLOT

The analysis established which research keywords had been used most frequently (right) by different affiliations (middle) and countries (left). The study of the top keywords, affiliations, and countries indicated that there were five keywords (decision-making, sustainable development, COVID-19, human health and risk assessment) and four countries (USA, China, India, and Iran) supported by five institutions (Indian Institute of Technology Bombay, Kth Royal Institute Of Technology, Tsinghua University, Cebu Technological University, Cebu Technological University, and

China University of Geosciences) as shown in the Sankey diagram, given in Fig. 3 (Kumar & Goel, 2021).

### 3.5. COUNTRY COLLABORATION MAP

The country's collaboration map is used to measure the international collaboration intensity of a country. Australia and Canada are the countries with the strongest contribution, and the UK is symbolised by the dark blue colour. According to Fig. 4, Bangladesh is the country where several documents were written by five co-authors, followed by Brazil with one collaboration (El Baz & Iddik, 2021).

### 3.6. FACTORIAL MAP OF THE DOCUMENTS

For each cluster of the conceptual structure map, the factorial map of the documents with the most contributions identifies the group of papers using mainly specific keywords. As this analysis is based on the use of a keywords co-occurrence network, the

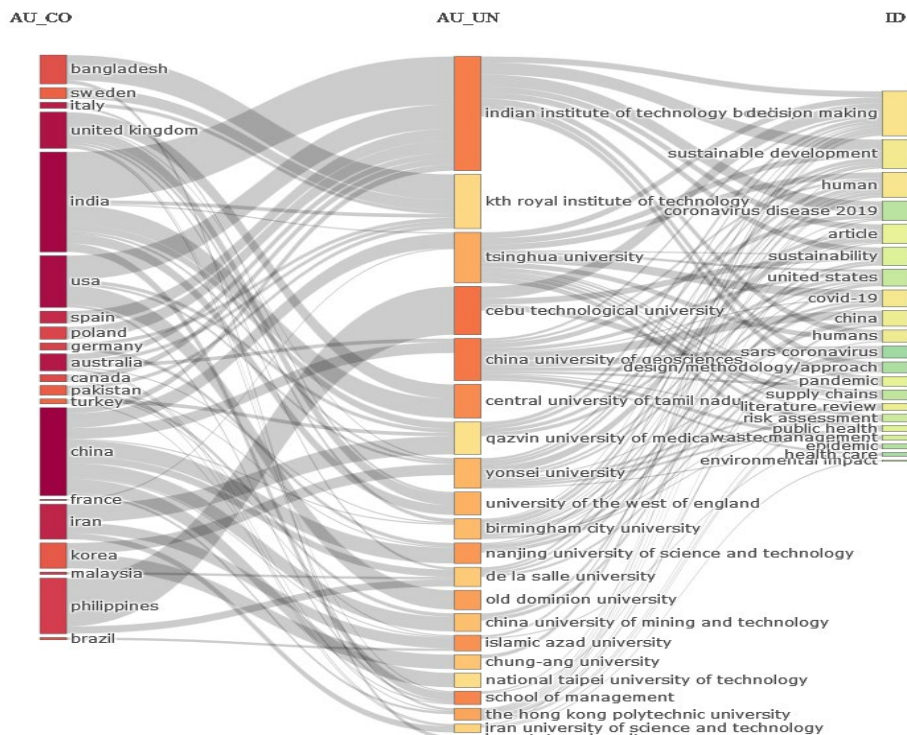


Fig. 3. Three-Fields Plot keyword (right), affiliations (Middle), and countries (left) (Sankey diagram)

Tab. 8. Countries' collaboration worldwide

From	To	Frequency	From	To	Frequency	From	To	Frequency
AUSTRALIA	BANGLADESH	3	AUSTRALIA	NORWAY	1	BRAZIL	PAKISTAN	1
AUSTRALIA	CANADA	3	AUSTRALIA	PAKISTAN	1	CANADA	COLOMBIA	1
AUSTRALIA	DENMARK	1	AUSTRALIA	POLAND	1	CANADA	FINLAND	1
AUSTRALIA	FINLAND	1	AUSTRALIA	QATAR	1	CANADA	GREECE	1
AUSTRALIA	FRANCE	1	AUSTRALIA	SINGAPORE	2	CANADA	INDONESIA	1
AUSTRALIA	GERMANY	2	AUSTRALIA	SOUTH AFRICA	1	CANADA	IRELAND	2
AUSTRALIA	GREECE	1	AUSTRALIA	SPAIN	2	CANADA	JAPAN	1
AUSTRALIA	HONG KONG	2	AUSTRALIA	SWEDEN	2	CANADA	MEXICO	1
AUSTRALIA	IRAN	1	AUSTRALIA	SWITZERLAND	2	CANADA	NETHERLANDS	2
AUSTRALIA	IRAQ	1	AUSTRALIA	YEMEN	1	CANADA	NEW ZEALAND	2
AUSTRALIA	IRELAND	2	AUSTRIA	HUNGARY	1	CANADA	NIGERIA	1
AUSTRALIA	ITALY	1	AUSTRIA	TUNISIA	1	CANADA	NORWAY	1
AUSTRALIA	MALAYSIA	2	BANGLADESH	JAPAN	1	CANADA	SINGAPORE	1
AUSTRALIA	MEXICO	1	BANGLADESH	NETHERLANDS	1	CANADA	SOUTH AFRICA	1
AUSTRALIA	NETHERLANDS	3	BANGLADESH	NIGERIA	1	CANADA	SWEDEN	2
AUSTRALIA	NEW ZEALAND	1	BANGLADESH	PAKISTAN	1	CANADA	SWITZERLAND	1
AUSTRALIA	NIGERIA	1	BANGLADESH	SWEDEN	1			

papers mentioned in each cluster identified the connections among the keywords (Lamboglia et al., 2020) (e.g., one paper could use two or more of those keywords). Fig. 5 shows one cluster (red colour) consisting of various elements of the documents of the highest contributions. The similarity is measured by the distance between any row points or column points (Syed & Bawazir, 2021).

Fig. 5 highlights the most contributing documents using a factorial map. Since Bibliometrix –

R tool allows factorial analysis to determine the conceptual structure of the bibliometric data; it is an interesting black-box-based alternative to view the cluster components based on closeness calculated using the Correspondence Analysis (CA) multivariate statistical technique (Ghosh & Prasad, 2021). The dimensions or factors considered are keywords (no documents per author) and Total Citations (TC).

As observed in the figure, the documents appeared in one cluster across two dimensions

### Country Collaboration Map

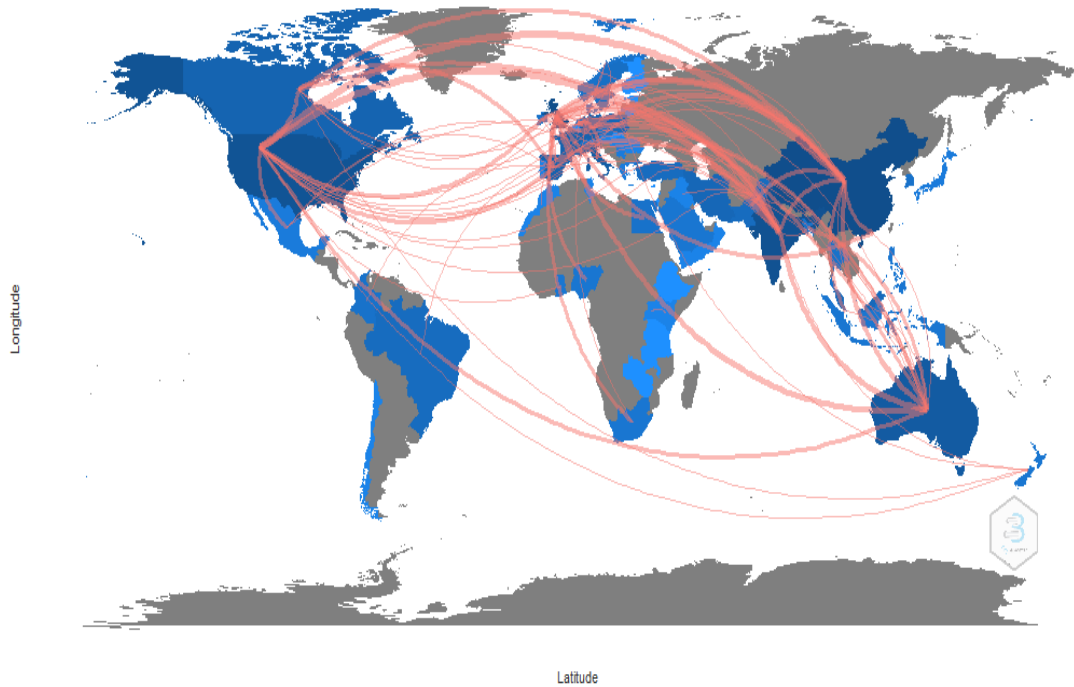


Fig. 4. Country collaboration map on keywords literature around the world

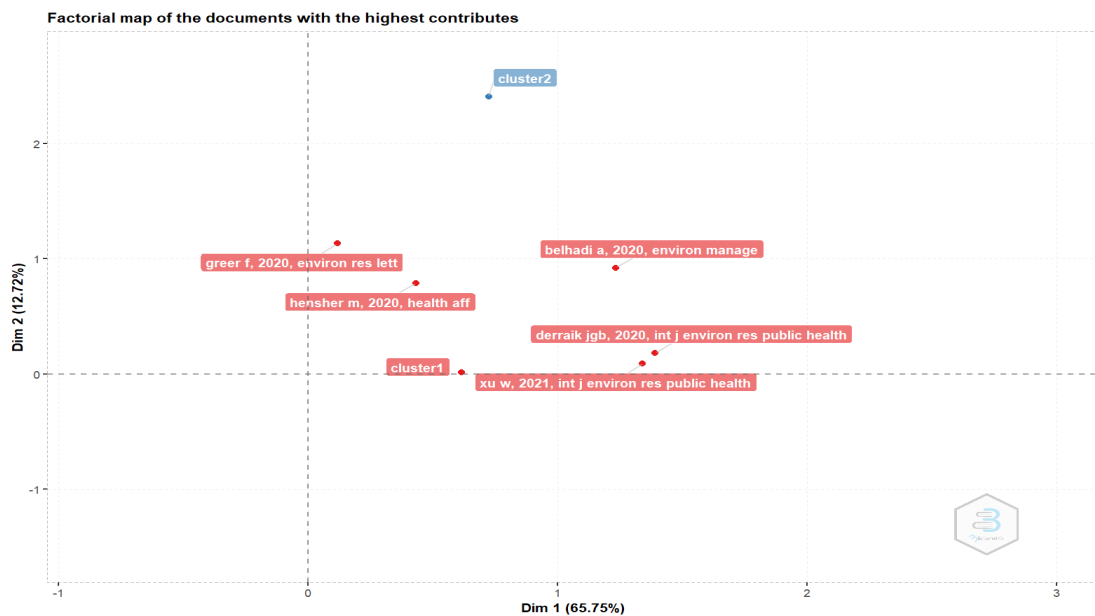


Fig. 5. Factorial map of the documents with the highest contributions

(DIM1=key words; DIM2=total citations). Five documents from Cluster 1 are ranked with the highest contributions as they fall under the positive quadrants of both dimensions. Cluster 1 explains the effect of COVID-19 risks on human health. For example, Belhadi et al. (2020), in the article “Infectious waste management strategy during the COVID-19

pandemic in Africa”, studied an integrated decision-making framework for selecting sustainable technologies in environmental management.

In addition, as shown in the figure, Xu et al. (2021) presented a study on the influence of COVID-19 on community disaster resilience.

## CONCLUSIONS

After analysing 208 articles and 73 keywords, the six identified clusters (the effect of Covid-19 risks on human health, supply chain in construction projects and industry, disaster risk management in a changing climate, sustainable supply chain benchmarking, facility management and quality control and finally, and sensitivity analysis and decision-making) revealed that the COVID-19 pandemic has a continuous and direct impact on sustainable development goals, specifically human health, and care in various work communities, such as construction projects and the industry, where risk management must be applied strongly to minimise the dangers of both the individual and the work environment. This can be accomplished by implementing supply chain management to improve internal and external efficiency, reduce waste, and improve productivity.

Sustainable Supply Chain Management (SSCM) is viewed as a promising integrated sustainable development framework, and benchmarking can be a learning method for organisations. External standards and what and how other comparable companies have performed can be incorporated into their organisational procedures.

In addition, risk management is an important field in facility management because it serves the built environment. Thus, research in the field of risk management and prevention of COVID-19 in projects and facilities needs an integrated approach. Research in this specific risk management area should give more weight, at least in some areas, to the perspectives of facility managers and other people responsible for the built environment. The benefit of statistical quality control is that it provides the facility managers with the ability to make some sense of the results being achieved in virtually any repetitive procedure for which they are responsible, so the benchmarking becomes a part of the total quality management for facility management to improve and increase the efficiency of decision-making.

Among the limitations of the study, two aspects can be pointed out. The first is that the bibliometric analysis did not consider publications from other databases with a lower impact, such as Google Scholar, EBSCO and PubMed. Secondly, the clustering of the analysis may lead to concepts that are spread across both clusters, and in the future, they may become central to research in sustainable facilities management in the post-COVID period.

The effects of COVID-19 seem to have been largely overcome or learned to cope with, but political-economic instability continues to pose new problems that call for future research on sustainable facility management, new supply chain challenges in construction projects and ways to improve risk management in uncertain scenarios.

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