

REPUBLIC OF TURKEY
YILDIZ TECHNICAL UNIVERSITY
GRADUATE SCHOOL OF SCIENCE AND ENGINEERING

**SCIENTOMETRIC ANALYSIS OF MATERIAL
RECYCLING IN SUSTAINABLE CONSTRUCTION**

Ghadah HASHOOSH

MASTER OF SCIENCE THESIS
Department of Civil Engineering
Civil Engineering Program

Supervisor

Prof. Dr. Asli GÜRGÜN

November, 2023

REPUBLIC OF TURKEY
YILDIZ TECHNICAL UNIVERSITY
GRADUATE SCHOOL OF SCIENCE AND ENGINEERING

SÜRDÜRÜLEBİLİR İNŞAAT UYGULAMALARINDA
MALZEME GERİ DÖNÜŞÜMÜNÜN SCİENTOMETRİK
ANALİZİ

A thesis submitted by Ghadah HASHOOSH in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE is approved by the committee on 22.11.2023 in Department of Civil Engineering, Civil Engineering Program.

Prof. Dr. Asli GÜRGÜN
Yildiz Technical University
Supervisor

Approved By the Examining Committee

Prof. Dr. Asli GÜRGÜN, Supervisor
Yildiz Technical University

DR.ÖĞR.ÜYE. Kerim KOÇ, Member
Yildiz Technical University

Prof. Dr. Gül POLAT , Member
Yildiz Technical University

I hereby declare that I have obtained the required legal permissions during data collection and exploitation procedures, that I have made the in-text citations and cited the references properly, and that I haven't falsified and /or fabricated research data and results of the study. In addition, I have abided by the principles of scientific research and ethics during my Thesis Study under the title of "Scientometric Analysis of Material Recycling in Sustainable Construction" supervised by my supervisor, Prof. Dr. Asli GÜRGÜN. In the case of discovering a false statement, I am to acknowledge any legal consequence.

Ghadah HASHOOSH

Signature



Dedicated to my family

And my friends

ACKNOWLEDGEMENTS

Through God's grace, I was able to reach this educational level. I would like to express my gratitude and appreciation to my supervisor Professor Asli Pelin GÜRGÜN for his guidance and contribution to the thesis.

Ghadah HASHOOSH



TABLE OF CONTENTS

LIST OF SYMBOLS	vii
LIST OF ABBREVIATIONS	viii
LIST OF FIGURES	ix
LIST OF TABLES	x
LIST OF MAPS	xi
ABSTRACT	xii
ÖZET	xiv
1 INTRODUCTION	1
1.1 Literature Review	1
1.2 Objective of the Thesis	19
1.3 Hypothesis	19
1.4 Problem Statement	19
1.5 Research Questions	20
1.6 Research Significance	21
1.7 Methodology	21
1.8 Thesis Structure	23
2 RECYCLE CONSTRUCTION WASTE	24
2.1 Introduction	24
2.2 Academic Research	24
2.3 The implications of incorporating robust sustainability into business 'literature and practice'	27
2.4 Sustainable Construction: Challenges and Opportunitie.....	28
2.5 Recycle construction waste	29
2.6 The life cycle of waste recycling.....	30
3 METHOD AND METHODOLOGY	32
3.1 Introduction	31
3.2 Construction Waste	33
3.4 Methods	40
4 RESULTS AND DISCUSSION	58
4.1 Introduction	58

4.2 Documents searched in Scopus database	58
4.3 Annual Publication Trend	60
4.4 Top Keywords with the most citation bursts	61
4.5 Productive Countries in Construction Waste Management Studi.....	62
4.6 Contributing Authors	66
4.7 The Most Important Sources for Construction Waste Management Studies.....	66
5 CONCLUSIONS AND RECOMMENDATIONS	68
5.1 Conclusions	68
5.2 Recommendations	70
REFERENCES	71
PUBLICATIONS FROM THE THESIS	84



LIST OF SYMBOLS

& And

% Percentage



LIST OF ABBREVIATIONS

BRE	Building Research Institute
CIB	Innovation in Building and Construction
C&D	Construction and Demolition
CO ₂	Carbon Dioxide Gas
CVS	Consumer Value Stores
ESD	Environmental Sustainable Development
GHGs	Greenhouse Gases
ITZ	Interfacial Transition Zone
LCA	Life Cycle Assessment
LEED	Leadership in Energy and Environmental Design
MSW	Municipal Solid Waste
OPC	Ordinary Portland cement
RA	Recycled aggregate
RAC	Recycled aggregate concrete
SCMs	Secondary Cementitious Materials
SWM	Solid Waste Management
UNEP	United Nations Environment Program
VOC viewer	Volatile Organic Compound Viewer
WGBC	World Green Building Council
WCB	Clay brick

LIST OF FIGURES

Figure 1.1	The sustainability pyramid for waste recycling [1]	1
Figure 1.2	Life cycle of a building for construction waste management [1]	2
Figure 1.3	Pillars of sustainability [2]	6
Figure 1.4	From a linear to a circular economy [8]	7
Figure 1.5	Thesis Structure	23
Figure 2.1	Annual MSW generation from selected countries [72]	27
Figure 2.2	An analysis of components resulting from the demolition building...30	
Figure 2.3	The life cycle of waste recycling [68]	31
Figure 3.1	Scientometric analysis planner (Research methodology)	33
Figure 3.2	Chemical analysis of Rubber [64]	37
Figure 3.3	Chemical analysis of glass waste [64]	38
Figure 4.1	Sequence followed for scientometric analyze [96]	58
Figure 4.2	Document results before/ after applying filters	59
Figure 4.3	Classifying articles according to keywords within the scope of the search.....	60
Figure 4.4	Annual publication trend of articles	61
Figure 4.5	The percentage of search words	62
Figure 4.6	Top contributing countries	63
Figure 4.7	Top five countries in the number of publications	64
Figure 4.8	Top ten publishing Arab countries	65
Figure 4.9	Top contributing authors in the relevant	66
Figure 4.10	The most productive sources for articles	67

LIST OF TABLES

Table 1.1 Economy of Resources Principle [22],[23].....	13
Table 1.2 Human Design Principle [22],[23]	14
Table 3.1 Top 15 articles with highest citations.....	41
Table 3.2 Documents searched in Scopus database until March 2023	45
Table 3.3 Number of articles per year and Total Citations	46
Table 3.4 Top 15 most contributing countries in the relevant field	48
Table 3.5 Contributing Arab countries in the relevant field	50
Table 3.6 Top Keywords with the most citation bursts	52
Table 3.7 Top contributing authors in the relevant field.....	54
Table 3.8 List of publication sources with a number of articles in the relevant field.....	56

LIST OF MAPS

Map 3.1 Science mapping for most cited articles	44
Map 3.2 The Network Visualization and Density Visualization of most contributing countries in The relevant field	49
Map 3.3 A Network Visualization map for Arab countries contribute to the relevant field	51
Map 3.4 Overlay Visualization map for keywords	53
Map 3.5 Science network visualization map for Co-authorship	55
Map 3.6 Science network visualization map for sources	57



Scientometric Analysis of Material Recycling in Sustainable Construction

Ghadah HASHOOSH

Department of Civil Engineering

Civil Engineering Program

Master of Science Thesis

Supervisor: Prof. Dr. Asli GÜRGÜN

Sustainability in any field means the ability to meet certain requirements of a particular sector without prejudice to the rights of future generations, and this sustainability must achieve what is called economic sustainability, environmental sustainability, and social sustainability.

This sustainability must take place in several phases in parallel to be more effective and economically sustainable, as economic activity will increase with the increase in people's demand for the market and the purchase of recycled products, achieving environmental sustainability by recycling waste instead of burning it or burying it underground. Thus protecting the environment from damage is a right of future generations before it is a right of current generations. Therefore, the sustainability of references is the basis for practical sustainability, as the availability of research and studies saves a lot of effort and money and gives many solutions to achieve environmental sustainability, economic sustainability, and social sustainability to achieve integrated sustainability.

The sustainability of buildings is like any sector, so recycling concrete waste in particular, and building debris, in general, is one of the most important ways to achieve sustainability in this field. Sustainability of the environment can be accomplished by recycling these wastes rather than burning or burying them. Additionally, it prevents the depletion of natural resources that benefit both present and future generations, thereby achieving sustainability. However, in order to achieve economic sustainability, trash must be recycled and used again in buildings as a substitute for cement and other materials. Research on recycling construction debris has been documented, but even if studies and research have been conducted by Arab scholars, the percentages of documentation and citation are extremely low, and the necessary referential sustainability is barely met. Moreover, sustainability in the Middle East and the Arab countries in particular is still in the early stages of achieving full sustainability, which is economically, environmentally, and socially sustainable, since reference sustainability is the first step towards achieving practical sustainability in the construction waste recycling facilities.. In a table that is simple to reference, we have compiled studies by scientometric analysis, research, and articles on recycling from 2010 to 2023. This table also includes the most crucial keywords, the most crucial sources of production and publication of articles, and maps that explain this. The most important building wastes have been highlighted, together with an explanation of the most important recycled materials and their characteristics in an effort to achieve sustainability in the field of construction management as a whole. References have also been linked, and integrated to achieve practical sustainability.

Keywords: Sustainability, Economically, Socially, Requirements, Scientometric analysis

Sürdürülebilir İnşaat Uygulamalarında Malzeme Geri Dönüşümünün Scientometric Analizi

Ghadah HASHOOSH

İnşaat Mühendisliği Anabilim Dalı

Yüksek Lisan Tezi

Danışman: Prof. Dr. Asli GÜRGÜN

Her alanda sürdürülebilirlik, gelecek nesillerin hakları saklı kalmak kaydıyla, belirli bir sektörün belirli gereksinimlerini karşılayabilme yeteneği anlamına gelir, ve bu sürdürülebilirlik, ekonomik sürdürülebilirlik, çevresel sürdürülebilirlik ve sosyal sürdürülebilirlik denen şeyi başarmalıdır.

İnsanların pazara olan talebinin artması ve geri dönüşümlü ürünlerin satın alınması ile ekonomik aktivite artacağından, bu sürdürülebilirliğin daha etkin ve ekonomik olarak sürdürülebilir olması için paralel olarak birkaç aşamada gerçekleşmesi gerekir, atıkları yakmak veya yer altına gömmek yerine geri dönüştürerek çevresel sürdürülebilirliği sağlamak. Dolayısıyla çevreyi zararlardan korumak, şimdiki nesillerin hakkı olmadan önce gelecek nesillerin hakkıdır. Bu nedenle, referansların sürdürülebilirliği pratik sürdürülebilirliğin temelidir, araştırma ve çalışmaların mevcudiyeti çok fazla çaba ve para tasarrufu sağladığından ve çevresel sürdürülebilirliği sağlamak için birçok çözüm sunduğundan, entegre sürdürülebilirliği sağlamak için ekonomik sürdürülebilirlik ve sosyal sürdürülebilirlik. Binaların sürdürülebilirliği her sektörde olduğu gibi, bu nedenle özelde beton atıklarının, genel olarak da yapı molozlarının geri dönüşümü bu

alanda sürdürülebilirliği sağlamanın en önemli yollarından biridir. Bu atıkları yakmak veya gömmek yerine geri dönüştürmek aslında çevresel sürdürülebilirliktir. Aynı zamanda bizim ve gelecek nesiller için olan doğal kaynakların kullanımından tasarruf sağlar ve bu nedenle sürdürülebilirliği sağlamış olabiliriz. Öte yandan, ekonomik sürdürülebilirliğin sağlanması için atıkların geri dönüştürülmesi ve inşaat faaliyetlerinde çimento ve diğerlerine alternatif olarak tekrar kullanılması gerekmektedir. Arap araştırmacılar tarafından yapılan araştırma ve çalışmaların varlığına rağmen, inşaat atıklarının geri dönüşümü konusunda yapılan araştırmaların belgelenmesi, belgeleme ve atıf yüzdeleri çok düşüktür ve gerekli referans sürdürülebilirliği neredeyse hiç sağlanamaz. Ayrıca referans sürdürülebilirlik, inşaat atıkları geri dönüşüm tesislerinde pratik sürdürülebilirliğe ulaşmanın ilk adımı olduğundan, Orta Doğu bölgesi ve Arap ülkelerinde inşaat atıkları alanında genel olarak sürdürülebilirlik, özellikle ekonomik, çevresel ve sosyal olarak tam sürdürülebilirliğe ulaşma yolunda ilk adımlarını atmaya devam etmektedir. Referans vermesi kolay bir tabloda, 2010'dan 2023'e kadar geri dönüşümle ilgili scientometric analiz, araştırma ve makalelerle yapılan çalışmaları derledik. Bu tablo aynı zamanda en önemli anahtar kelimeleri, makalelerin üretimi ve yayınlanması için en önemli kaynakları ve bunu açıklayan haritaları da içermektedir. Genel olarak inşaat yönetimi alanında sürdürülebilirliği sağlamak için, Referanslar birleştirildi, pratik sürdürülebilirlik ve bunları birbirine bağladı ve ayrıca en önemli inşaat atıklarından bazılarının altını çizdi ve bunların nasıl geri dönüştürülüp bundan kâr elde edileceğini gösterdi.

Anahtar Kelimeler: Sürdürülebilirlik, Ekonomik, Sosyal, Gereksinimler, Scientometric analizi.

1.1 Literature Review

1.1.1 Introduction

Sustainability is the achievement of specific needs in the present without compromising the rights of future generations. To ensure global sustainability and effective management of environmental, economic, and social resources, long-term growth strategies need to be integrated and changed. The industrial sector, which both consumes resources and contributes to pollution, must adopt practices such as reuse, recycling, and environmentally integrated production. These practices are crucial in providing alternative solutions, as the construction sector, being a significant energy consumer, emits harmful gases like carbon dioxide (CO₂) during waste burning or recycling processes. Consequently, the construction sector's impact on the environment is negative. Therefore, prioritizing sustainability in the construction industry is crucial (see Figure 1.1).

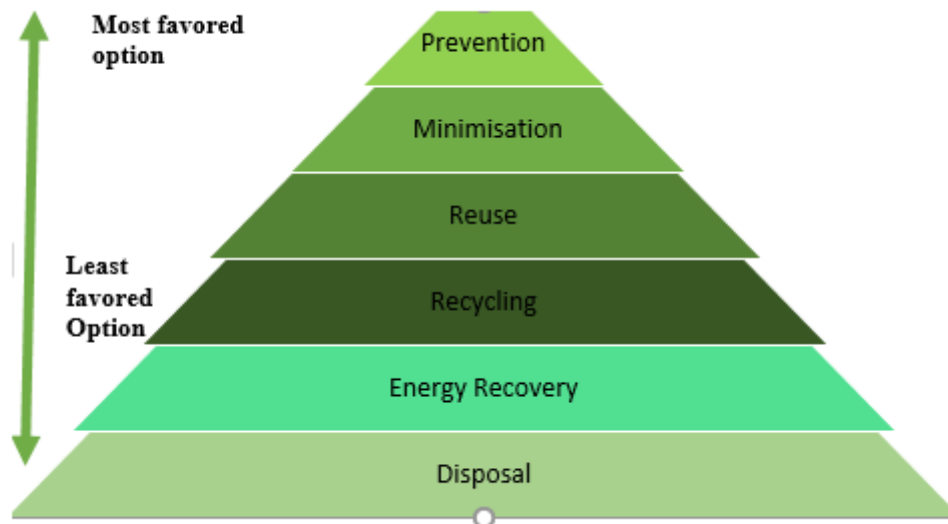


Figure 1.1 The sustainability pyramid for waste recycling [1]

The hierarchical structure of waste recycling processes, including construction waste, is depicted in Figure 1.1. Construction waste, which amounts to thousands of tons annually, poses environmental and health risks due to its toxicity. Disposal methods such as burial or burning contribute to carbon dioxide emissions and soil damage, underscoring the importance of recycling waste in general and construction waste in particular.

Figure 1.2 also presents the life cycle of construction waste recycling. It begins with waste collection, followed by transportation to recycling plants. The waste is then sorted into its different components for recycling and manufacturing purposes. Concrete, ceramic, and brick waste can be transformed back into aggregates for reuse, while rubber, glass, plastic, and cork waste can be converted into geopolymer compounds, offering both resource conservation and cost savings, thereby promoting economic sustainability.

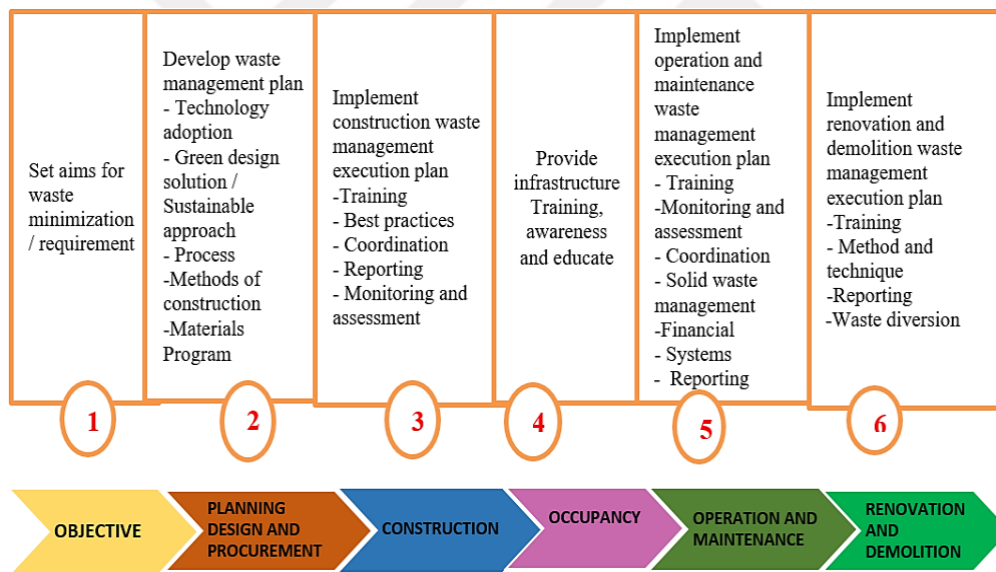


Figure 1.2 Life cycle of a building for construction waste management [1]

The existing economic models within the sustainable development system have led to environmental problems, resulting in the decline of societal wealth and living standards. The Brundtland Report in 1989 warned about the diminishing natural resources and the potential inability to meet human needs, which could halt or even hinder economic progress and social development [1]. While concerns have been raised over the years, countries, organizations, businesses, institutions, and

employers have come to recognize the imminent danger faced by humanity. The Brundtland Report emphasized the concept of sustainability, which entails meeting current needs and expectations while safeguarding the rights of future generations. This principle forms the foundation for proposed solutions to address the challenges of sustainable development.

The challenges to achieving sustainable development were examined in this context, along with research goals and problems that specifically highlight the significance of putting recycling materials under scientific study in order to produce sustainable structures.

Since the 1970s, there has been a growing interest in environmental economics and sustainability. During this period, a considerable amount of environmental research has focused on the concept of environmental sustainable development (ESD). It has been recognized that the construction industry plays a significant role in depleting natural resources and emitting harmful greenhouse gases (GHGs) through the combustion of fossil fuels. These activities have detrimental effects on the environment, leading to an imbalance and failure to achieve the necessary sustainability. Consequently, global warming, the depletion of the ozone layer, and their harmful impacts on the environment have become increasingly evident [2]. Sustainability refers to meeting present requirements while safeguarding the rights of future generations. To achieve global sustainability and efficient resource management, it is crucial for sustainable development and growth to incorporate environmental, economic, and social factors. This necessitates a shift in long-term growth strategies. The construction industry, which heavily relies on substantial quantities of natural and processed materials for structures, infrastructure, transportation, and environmental applications, plays a major role in resource consumption. However, the extraction and processing of these materials demand significant amounts of energy and natural resources, leading to the emission of greenhouse gases.

1.1.2 Sustainability

Environmental sustainability and environmental economics have been significant areas of research since the late 1970s. Numerous studies and research efforts have

focused on the concept of environmental sustainability development (ESD), recognizing that activities related to natural resources and the combustion of fossil fuels contribute to environmental damage [3]. Sustainability, in any field, can be defined as meeting the needs of the present generation while safeguarding the rights and needs of future generations. It encompasses ethics, principles, laws, and organizational aspects, providing a comprehensive framework for decision-making [4]. Sustainable development is often described as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" [5]. In 2006, the concept of environmental sustainability evolved into a long-term concept that emphasizes the optimal use of the environment, the preservation of resources, and the protection of future generations' rights. This expanded perspective encompasses the construction sector, which is known to be highly resource-intensive and environmentally damaging [6].

Sustainability in the context of environmental research is often described as a comprehensive approach that encompasses economic and social considerations. It entails meeting the needs of the current generation while safeguarding the rights and needs of future generations, whether they pertain to the economy, environment, or society. To achieve sustainability, it is crucial to incorporate planning and design, as well as the practical implementation of sustainable practices [7]. This holistic approach, referred to as referential sustainability and practical sustainability, prioritizes the preservation of environmental resources and the fulfillment of present and future generations' requirements and rights.

Sustainability encompasses the preservation of natural resources while also ensuring the well-being and rights of humanity [8]. It is often described as a multi-dimensional system with the goal of improving living standards and enhancing the overall quality and comfort of life [9]. The objective is to establish mutual interests among all individuals, supported by an environmental, economic, and social framework that benefits everyone. In essence, sustainability strives to achieve temporal and spatial balance for humans, ensuring equal access to environmental resources and a prosperous social and economic life. This balance can only be achieved by simultaneously pursuing environmental, social, and economic sustainability. Environmental sustainability entails maintaining a harmonious

relationship between the environmental, economic, and social components. Economic sustainability focuses on strategic development by ensuring environmental balance, while social sustainability emphasizes the well-being of communities. Therefore, it is crucial to recognize that sustainable development necessitates progress in environmental, economic, and social domains [10]. Moreover, sustainability is an ongoing process that begins with scientific and practical analyses, encompassing both theoretical and applied aspects.

Referential sustainability involves providing articles, research, and studies that facilitate the availability of information and data. This enables planning and implementation to be carried out in a scientific and practical manner. It also entails ensuring the availability of publication sources and the production of articles and studies. By employing scientometric analysis, which is a scientific approach to data analysis and planning, practical and scientific sustainability can be achieved. This approach is crucial for success in attaining practical sustainability.

Therefore, in line with the sustainable development strategy for any sector, strategic development must consider and promote environmental balance across economic, environmental, and social components. This approach is commonly referred to as environmental sustainability, economic sustainability, and social sustainability. It involves understanding and addressing the environmental, economic, and social aspects to ensure long-term sustainability.

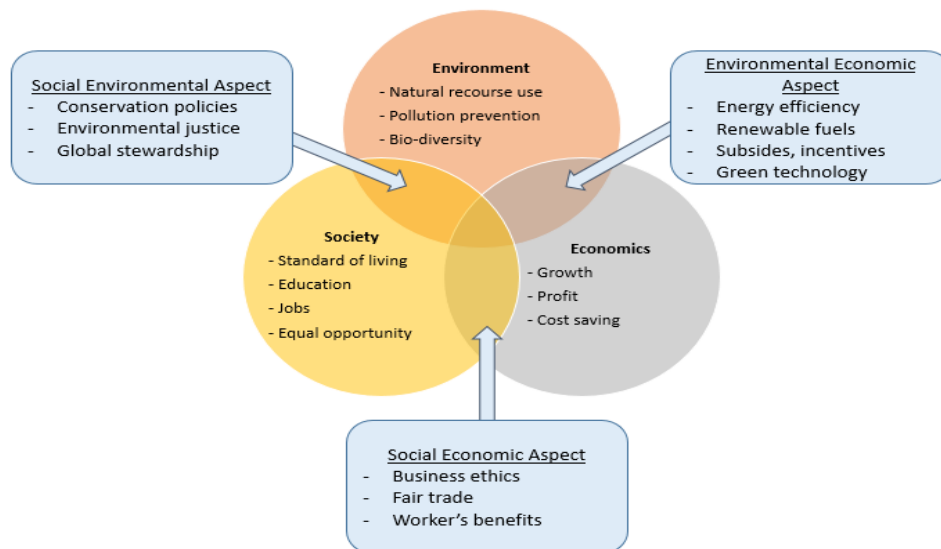


Figure 1.3 Pillars of sustainability [2]

1.1.2.1 Environmental Sustainability

In order to achieve the initial stage of sustainable development, it is crucial to consider environmental equilibrium. This involves ensuring the sustainability of resources, which entails their renewal, preservation, and efficient usage. An important aspect of achieving this balance is through the process of waste recycling, which allows for the extraction of raw materials while simultaneously producing new products that can be reused. However, it is vital to strike a careful balance, ensuring that the renewal of resources does not come at the expense of the environment and cause harm [11]. To accomplish this, it is necessary to preserve and protect the environment using various means, including:

- Supporting the elements of environmental life, which are essential for both specific ecosystems and life as a whole.
- Employing resources in a balanced manner and promoting resource conservation.
- Minimizing the release of environmental pollutants that pose harm to ecosystems and contribute to the destruction of our planet.
- Safeguarding our heritage and preserving the historical environment [7].

1.1.2.2 Economic Sustainability

In order to discuss economic sustainability comprehensively, it is necessary to first address the idea of economic development. Economic development refers to the ability of the market to generate production and consumption, specifically the growth of a nation's overall output and per capita income. However, it is important to consider the needs and rights of future generations while pursuing economic development. This involves creating value-added processes and embracing waste recycling as a crucial step towards achieving economic sustainability [8]. By recycling waste and utilizing it as a source of raw materials, we can produce new goods at a reduced cost. Therefore, the recycling of construction waste, for example, contributes to the promotion of economic sustainability within the construction industry.

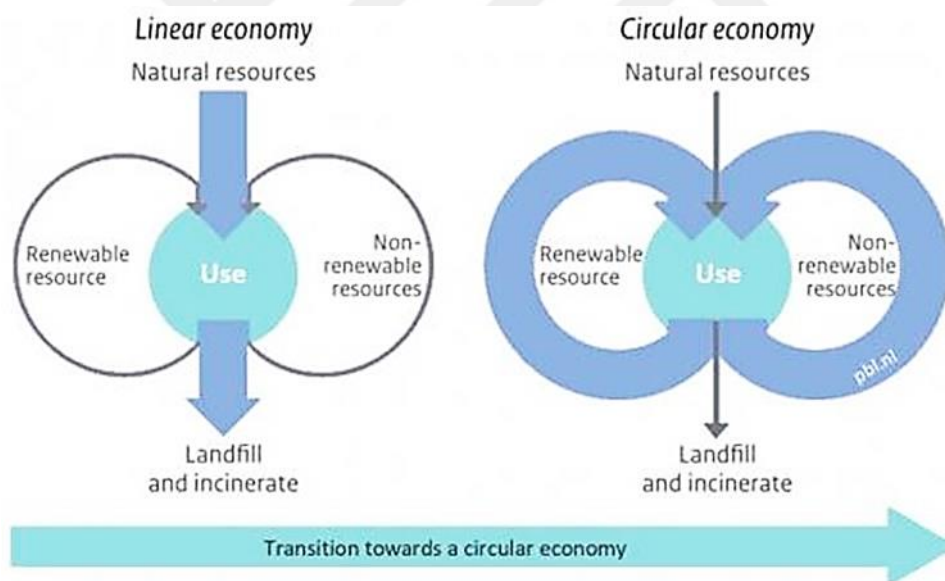


Figure 1.4 From a linear to a circular economy [8]

1.1.2.3 Social Sustainability

Social sustainability entails meeting the needs and rights of present and future generations while striving for social justice, ensuring equal opportunities for all individuals to lead dignified lives. To establish social justice and equilibrium, the following demands must be met:

1. Ensuring access to fundamental rights and basic necessities, including suitable housing, healthcare, education, employment, and a favorable environment.
2. Enhancing the overall quality of life for individuals and communities.
3. Rehabilitating and integrating individuals with disabilities into society.
4. Upholding the right for future generations to inherit a fresh start and promising prospects [8].

Sustainability, in its broadest sense, refers to meeting the needs of both present and future generations while safeguarding the rights and requirements of all generations. It entails achieving a state of balance, known as BEQUEST, which is recognized internationally. To ensure sustainability, various standards have been established at the global and regional levels, which must be adhered to [12]. Additionally, each country, and sometimes even municipalities within a country, have their own specific standards for sustainable system management. Compliance with these standards is crucial in attaining the desired level of sustainability. The higher the percentage of standards met, the stronger the sustainability and the greater its success.

1.1.3 Sustainable Development Strategies

Sustainable development is commonly understood as the pursuit of improving human life while operating within the limits of the Earth's carrying capacity. This definition has been shaped by various human rights and international organizations, which have identified nine fundamental principles and requirements for achieving sustainability. These include [13]:

1. Social Welfare: Prioritizing the well-being and quality of life for all individuals within society.
2. Income Enhancement: Striving to improve income levels and economic opportunities for everyone.
3. Healthcare: Ensuring access to adequate healthcare services for all individuals.

4. Reduction of Non-renewable Resource Consumption: Promoting the responsible and efficient use of finite resources.

5. Environmental Protection: Taking measures to safeguard the planet's ecosystems and biodiversity.

6. Education: Emphasizing the importance of education for sustainable development and fostering knowledge sharing.

7. Global Legislation: Working towards the formulation of international laws and regulations to promote sustainability across all sectors, including construction.

These principles and requirements provide a comprehensive framework for achieving sustainability and serve as a guide for addressing various societal and environmental challenges.

1.1.4 Sustainability and Globalization

In order to achieve the initial stage of sustainable development, it is crucial to consider environmental equilibrium. To establish sustainability as a widely embraced principle, it is essential for major companies, followed by countries and governments, to prioritize the application of sustainable development principles across environmental, economic, and social aspects. This approach ensures competitiveness, as numerous studies have demonstrated that renowned companies, which have become household names, have successfully implemented sustainable development practices. Subsequently, public and social awareness should promote the concept of sustainable development by presenting compelling examples of the benefits it offers, such as achieving social harmony and economic profitability. It is important to counter the prevailing misconception that sustainable development hinders profit and leads to higher production costs. On the contrary, sustainable development actually reduces production costs, enhances competitiveness, and fosters long-term market viability.

1.1.5 Sustainability and Competitiveness

The significance of sustainable development is widely recognized across various

sectors, including companies, institutions, organizations, and even governments. They all understand the importance of attaining balance to ensure market longevity and competitiveness, ultimately leading to profits [14]. As profit generation remains the primary objective for businesses and owners, sustainable development often takes a backseat. However, it is crucial for these entities to acknowledge the concept of zero-cost giving and strive to enhance the implementation of sustainable development principles to enhance their economic performance. By doing so, they can achieve sustainable development goals and improve their capacity to adapt to these principles. This, in turn, will enhance their competitiveness, market longevity, and economic support through profit generation [15].

1.1.6 Sustainability and Competitive

The most important ways to activate sustainability competitiveness:

1.1.6.1 Cost reduction and increased profit

Many business owners hold a misconception that implementing economic sustainability leads to a decrease in profits [16]. However, this notion is entirely incorrect and stems from the past, specifically the 1970s and 1980s, when environmentally friendly products with poor quality but high costs performed poorly in the market, resulting in lower profits. In reality, the concept of sustainability aims to enhance both the productivity and purchasing power of the market [17]. Productive power entails increasing production while reducing costs, ultimately leading to increased profitability. Therefore, sustainability cannot be compromised with non-profitability, as its primary objective is to enhance economic efficiency and elevate people's standards of living. This can only be achieved through the presence of profits.

1.1.6.2 Improve a brand image and attract consumers

Institutions and companies that apply sustainability and achieve profitability are always successful companies with famous and successful brands. They make a lot of money from these distinctive brands.

1.1.6.3 Risk mitigation

The increase in energy costs has necessitated a thorough examination of attaining sustainability within the energy sector. This approach serves as a means to achieve both economic and environmental sustainability by addressing issues related to pollutants and harmful gas emissions [17]. The competitive nature of businesses and the drive for improved performance push companies and business owners to elevate their operations and strive for increased profits [17].

1.1.6.4 Recruitment and retention of employees

Sustainable social and economic practices have a positive impact on the productivity, engagement, and motivation of employees and workers. Additionally, these practices fulfill their needs, improve their quality of life, and ensure the realization of their fundamental human rights [17].

1.1.6.5 Alternative resources

In light of the imminent depletion of natural resources like fuel and fossil fuels, it is crucial that we take measures to safeguard these resources. We must focus on utilizing them only in cases of extreme necessity while also developing strategies to recycle and repurpose waste and byproducts. The foremost plans and steps should revolve around implementing effective waste recycling and management systems.

Efficient waste recycling plays a pivotal role in preserving natural resources. By implementing recycling processes, we can recover valuable materials from waste streams and reintegrate them into the production cycle. This not only reduces the demand for virgin resources but also minimizes the environmental impact associated with their extraction and processing.

To effectively address resource depletion, it is crucial to prioritize waste reduction and adopt sustainable practices. This involves promoting responsible consumption habits, encouraging the use of eco-friendly materials, and implementing waste management systems that prioritize recycling and waste-to-energy conversion.

Additionally, research and development efforts should be directed towards advancing technologies that facilitate resource conservation. This includes exploring innovative recycling techniques, improving waste separation and sorting methods, and promoting the development of alternative and renewable energy sources.

Furthermore, education and awareness campaigns are vital for fostering a culture of resource conservation. By promoting understanding and consciousness about the finite nature of natural resources, we can encourage individuals, businesses, and governments to actively participate in waste reduction and recycling initiatives.

Safeguarding natural resources and mitigating the impacts of their depletion require a multifaceted approach. By focusing on waste recycling and reduction, adopting sustainable practices, advancing technology, and promoting awareness, we can work towards a more resource-efficient and environmentally conscious future.

1.1.6.6 Stay competitive on the market

According to a survey conducted by the MIT Sloan Management Review, approximately 66% of successful, growing, and competitive companies have prioritized sustainability in their operations [17]. These companies have recognized the importance of embracing sustainability practices in order to ensure their survival, promote growth, and remain competitive within their respective markets.

1.1.6.7 New revenue opportunities

Companies that aim for competitiveness, market growth, and long-term success are those that prioritize self-development and utilize cutting-edge technology to ensure sustainability [18]. These companies consistently demonstrate innovation by finding solutions to various challenges, allowing them to maintain continuity and experience ongoing growth.

1.1.7 Sustainability in Construction Sector

Throughout history, construction has been regarded as a vital aspect of any civilization, providing essential comfort and a sense of safety. However, the

construction sector has a significant impact on energy consumption, environmental resources, and water usage, particularly in urban areas [18]. According to data from 2010, buildings account for 45% of global energy consumption, 50% of water usage, 23% of air pollution, 50% of greenhouse gas emissions, and 40% of water pollution [19],[20],[21]. These pressing issues highlight the crucial challenges faced by the construction industry. To address them, the implementation of sustainability principles is necessary, encompassing energy efficiency, environmental preservation, economic viability, and social well-being. Without integrating sustainability practices, progress towards sustainability will remain elusive in all sectors, including construction.

Table 1.1 Economy of Resources Principle [22],[23]

Strategies	Method
Energy Conservation	Energy - conscious urban planning
	Energy - conscious site planning
	Alternative sources of energy
	Use of low embedded - energy materials
	Energy - efficient equipment & appliances
	Use of energy efficient appliances with timing devices
Water Conservation	Reuse water onsite (rainwater collection and gray water collection)
	Reduce consumption

Table 1.1 Economy of Resources Principle [22], [23] (continued...)

Material Conservation	Adaptation existing buildings to new uses
	Material conserving design and construction
	Incorporation reclaimed or recycled materials - use materials that can be recycle

Table 1.2 Human Design Principle [22],[23]

Strategies	Method
Preservation of Natural Conditions	Respect topographical contour
	Not disturbing the water table
	Alternative sources of energy
	Preservation existing flora and fauna
Urban Design Site Planning	Avoid pollution contribution
	Provision for human - powered transportation and design pedestrian roads
Design for Human Comfort	Provision thermal , visual , and acoustic comfort
	Daylighting and providing visual connection to exterior
	Provide clean , fresh air

1.1.8 Sustainable Construction Industry

Public opinion, both at a global and local level, undeniably wields significant influence on societal norms. This has resulted in a growing inclination among certain nations, such as China and the United States, to embrace sustainability through the adoption of green building strategies. These strategies aim to minimize energy consumption and preserve natural resources [24]. As a consequence, there has been a general consensus and concerted efforts towards achieving zero-energy construction practices within the next decade [25]. Green buildings, commonly recognized as such, are meticulously designed to mitigate adverse effects on both humans and the environment [26].

Embracing green buildings signifies the recognition and endorsement of strategies and measures aimed at achieving sustainability through the implementation of environmentally-friendly structures [10]. From the initial stages of planning and designing the building to its ongoing maintenance and operation, utmost consideration must be given to the environment.

The World Green Building Councils [11] is an organization dedicated to achieving zero energy consumption in construction. While this goal has not been fully realized, significant progress has been made over time, and the principles of green building are becoming increasingly widespread [12]. India, known for its prominent green building initiatives [27], defines green buildings as structures that minimize water consumption, maximize energy efficiency, protect the environment, and mitigate damage. To be classified as green buildings, construction processes must adhere to specific standards that prioritize energy and water conservation, resource efficiency, waste recycling, indoor air quality, and the creation of a healthy environment for occupants [28]. Various certification systems and specialized organizations, such as LEED (Leadership in Energy and Environmental Design) and BREEAM (Building Research Establishment Environmental Assessment Method), evaluate buildings and constructions based on these criteria. The first evaluation standard, called Priam, was developed and implemented by the Building Research Institute (BRI) in England in 1990. The World Green Building Council (WGBC), established in 1988 [10], has grown from 26 member states in 2007 to

over 98 member states today. Currently, more than 14,000 buildings are registered with the WGBC [11]. Green buildings have become exemplary models for many places, organizations, and countries, inspiring a shift towards sustainable construction practices [28].

1.1.9 An overview of sustainable construction

Sustainable development in the construction sector is making consistent progress [29]. According to Raynsford, sustainable construction involves employing methods that enable a profitable and competitive business to create environmentally friendly built assets such as buildings, structures, supporting infrastructure, and their immediate surroundings. This approach aims to achieve several objectives, including enhancing quality of life and ensuring client satisfaction, offering flexibility to accommodate future user changes, promoting desirable natural and social environments, and optimizing resource utilization.

Raynsford's concept emphasizes the importance of considering both the process and the output in sustainable development. It takes into account various aspects of social, economic, and environmental sustainability. However, this definition falls short of capturing all the implications associated with the phrase.

Achieving and maintaining high and stable levels of economic growth and employment while simultaneously protecting, and ideally enhancing, the environment and managing natural resources wisely are all examples of social progress. These three main issues, often referred to as the "triple bottom line," are central to sustainable development. In sustainable construction, multiple factors such as social, financial, and environmental dimensions are always taken into consideration. However, the interpretation and goals of sustainable construction can vary greatly depending on the context, as the demands and circumstances of affluent countries differ significantly from those of underdeveloped nations.

For instance, Gibberd's ideas were developed to promote sustainable construction specifically in underdeveloped countries like South Africa. Another example can be found in Ofori's commentary on Hill and Bowen's study [30], where Ofori argued that, although some concerns raised in the study were relevant to the South

African context, overall, it reflected the viewpoint of industrialized countries. Recognizing these disparities between industrialized and developing nations, the International Council for Research and Innovation in Building and Construction (CIB) and other organizations issued "Agenda 21 for Sustainable Construction in Developing Countries [20]." This agenda acknowledges that distinctions exist due to factors such as the scale of issues, development objectives, local industry and government capacity, levels of skills, as well as cultural and worldview influences that shape the understanding and implementation of sustainable development and construction.

Despite the importance of sustainable construction, there is still a lack of understanding about it in both developed and developing countries. For instance, a poll conducted in the Netherlands in 1998 revealed that a significant number of architects and building contractors were unaware of what sustainable construction entailed [31]. Similarly, research conducted in the United States by Landman identified a shortage of training and support in sustainable design and construction as a major barrier to the adoption of sustainable building methods [32]. In Kenya, Watuka and Aligula found that a considerable portion of professionals in the construction industry, including architects, engineers, quantity surveyors, and contractors, lacked understanding of sustainability practices [33].

Sustainable construction practices primarily aim to minimize harm to the environment by promoting the recycling of waste and reducing the consumption of natural resources. Unfortunately, some people mistakenly believe that sustainability and profitability are mutually exclusive, disregarding the potential economic benefits of sustainable construction [33]. This misconception often leads to conflicts between short-term economic development and long-term sustainable development. To address this, it is crucial to strike a balance between sustainable development and environmental preservation[34]. Achieving sustainability requires attaining harmony and equilibrium between environmental and economic considerations, which ultimately leads to social sustainability. A key step toward achieving this balance and harmony is to incorporate sustainability principles and steps into the feasibility study of any project.

1.1.10 Sustainable Construction Factors

Insufficient data on sustainability during construction projects, particularly in developing countries, poses a significant challenge that hinders the achievement of project goals. Despite the crucial role of the construction industry in providing infrastructure and supporting business growth, it exerts immense pressure on global natural resources. The meaning of sustainability varies among individuals, leading to a lack of standardized approaches. Hence, it becomes vital to establish clear principles of sustainable development specific to the construction sector, along with identifying the drivers, enablers, and barriers to sustainable construction projects. Various factors influence the sustainability of the construction sector, including effective project management methodologies, project complexity, innovation in project management practices, utilization of information technology, and more. Achieving a balance between social and economic development and environmental sustainability is crucial when evaluating the sustainability performance of construction projects. However, environmental considerations tend to receive more attention than other aspects in construction projects. While each country or region has its own strengths and weaknesses in addressing sustainability, the absence of sustainability reporting in the valuation process hampers further investment in sustainable practices. Even in industrialized nations like the United Kingdom, many construction organizations do not report on their sustainable practices, leading to a superficial understanding of sustainability among both office-based and site-based staff.

The construction industry faces several challenges when it comes to achieving sustainability. These challenges include a limited understanding of sustainability, inadequate research on sustainable practices, technological limitations, and the undervaluing of certain sustainable methods due to cultural factors. Additionally, the lack of awareness about sustainable practices is a significant obstacle. In developing countries, the absence of support from top management and the insufficient enforcement of government regulations further hinder the progress of sustainable construction [35].

1.1.11 Environmental Consequences of Construction Materials

The construction industry is a major consumer of raw resources, accounting for approximately 24% of global consumption [36]. Traditional construction materials like steel, concrete, aluminum, and glass require significant amounts of energy for production. The choice of materials used in construction plays a crucial role in determining the overall environmental impact of a building throughout its life cycle. Numerous studies have emphasized the importance of material selection, where low-energy materials can have a greater influence on the building's sustainability compared to operational energy use. Opting for materials with high energy consumption results in increased energy requirements during manufacturing and higher levels of greenhouse gas emissions [37].

However, according to the findings of Saghafi and Teshnizi [38], selecting sustainable building materials is a challenging task, as it involves considering various environmental factors associated with the materials and construction techniques. This area remains largely unexplored, with numerous variables and uncertainties that need to be addressed when assessing the environmental implications of building materials. It is important to recognize that building materials not only impact the built environment but also have consequences for the natural environment throughout their life cycle.

1.2 Objective of the Thesis

The objectives of the current study are as follows:

1. Identifying the importance of recycling materials in sustainable construction.
2. Researching the effects of recycling materials and construction waste on reducing CO₂ emissions, rates of global warming, and environmental pollutants.
3. Identifying the significance of conducting a scientometric analysis of material recycling in sustainable construction.

1.3 Hypothesis

We choose to emphasize the significance of recycling construction wastes for better quality of life and health, which should result in more sustainable construction, and the effect will be measured by comparing the CO₂ levels before and after the recycling process over the long term. This is because we have found that the building industry has a significant impact on the accumulation of solid wastes by measuring its contribution to global CO₂ emission.

1.4 Problem Statement

The rapid increase in industrialization, urbanization, and advancements in material science has led to a significant rise in solid waste production [39]. According to the United Nations Environment Program (UNEP) and the International Solid Waste Association, global urban waste production is estimated to range between 7 and 10 billion tons annually, with a substantial increase per capita over the past 50 years [40]. This growing concern for sustainability, driven by limited resources, has presented new challenges from administrative, tactical, and operational perspectives. The construction sector plays a vital role in meeting society's needs by improving living standards. The importance of research on sustainability in the construction industry cannot be overstated. Companies now recognize that maintaining a competitive edge requires more than just customer satisfaction based on low prices and high-quality products or services. Consumers prefer companies that uphold ethical principles and demonstrate social and environmental responsibility. Therefore, it is crucial to thoroughly investigate the sustainability of construction practices.

Various industries such as mining, manufacturing, agriculture, electricity generation, metalworking, and electronics production generate vast amounts of solid waste. Many of these wastes contain hazardous or reactive elements, making their disposal costly and environmentally damaging. Consequently, the construction industry is increasingly focusing on recycling and reusing solid waste materials. These waste products can be used in construction instead of cement or aggregates, conserving resources, reducing cement use, and lowering CO₂

emissions. A scientometric review on the recycling of waste materials in sustainable construction is what this work intends to do. Beyond the constraints of manual evaluations, scientometric analysis allows for the thorough investigation of enormous volumes of data, providing trustworthy insights and solidifying linkages between various works of literature.

1.5 Research Questions

The following are the objectives of the research questions:

1. How will recycling materials and waste construction contribute in reducing CO2 Emission?
2. What is the importance of recycling materials in Sustainable construction?
3. What are the benefits of conducting a scientometric analysis of material recycling in sustainable construction?

1.6 Research Significance

Recently, there has been a lot of research done to identify the elements that contribute to sustainable building, and some significant discoveries have been made. Historically, the majority of review studies were manually completed. This research explores how materials are used in construction as a sustainable method across a significant body of bibliometric data using scientometric analysis. Due to the huge volume of waste produced worldwide, landfill disposal has negative effects on the environment and public health. Experts from various geographical regions may benefit from the graphical depiction when forming research alliances, launching joint ventures, and exchanging cutting-edge technologies and concepts as a result of the study, depending on a scientometric evaluation.

1.7 Methodology

A scientific examination of bibliometric measurements was carried out during this study, information how to use waste products in construction was carried out [41]. The main justification for creating a scientometric review approach is because it

has been demonstrated that researcher-conducted subjective reviews of civil engineering studies are prone to wrong. Because it's indeed unaffected by anyone's point of view, scientometric gives a more logical and less skewed results when used alone [42]. The research collected over the previous two decades is compiled and synthesized in this study. Through the use of links between bibliometric data and maps, this study evaluates research development and generates an analytical evaluation. On the subject, a lot of documents have been written, so selecting the most accurate database is critical. Web of science and Scopus are the most effective, thorough, and used resources to make research studies [43]. Compared to Web of Science, Scopus has a wider bibliometric coverage and more recent data [43], [44]. The bibliometric data required for this analysis how waste material is used in concrete was compiled using Scopus. In August 2021, a search for bibliometric information was carried out in the Scopus database. The terms "recycle materials," "waste materials," "construction materials," and "sustainable construction" were searched in Scopus. Relevant articles were removed using data refinement tools. The drop- down menu's only selections were "review" and "article" for "document type". Additionally, the only option for "source type" was "journal," and the only option for "language" was "English." The "publication year" for this study was only between 2010 and 2023. The "Topic of study" of "building, environmental science, material science and recycling" was picked for additional analysis. The resulting documents were kept for study once these filters had been applied. Previously, researchers from a wide range of fields used similar methodologies [45],[46].

Science visualization is a method created by professionals that is used in scientometric reviews to examine scientometric data for a wide range of goals [47], identify the challenges faced by researchers, especially those who perform manual reviews and create sources and keywords with correlations, writers, papers, and nations in a particular study field [48]. The data was exported from the database in the comma separated values (CSV) format from Scopus for analysis, using the appropriate tools. VOS viewer was prepared to construct the visualization and science mapping. VOS viewer is visualization popular tool that is open-source and free, it has received positive reviews in the field [49],[50]. In order to achieve the

goals of the current study, the VOS viewer was employed. The CSV files for Scopus were imported into VOS viewer, where they were quickly and easily analyzed while preserving data consistency and dependability. The regions' involvement, the most popular authors and articles, the most frequently appearing keywords, and the sources of the articles were all examined as a part of the examination of the science mapping.

1.8 Thesis Structure

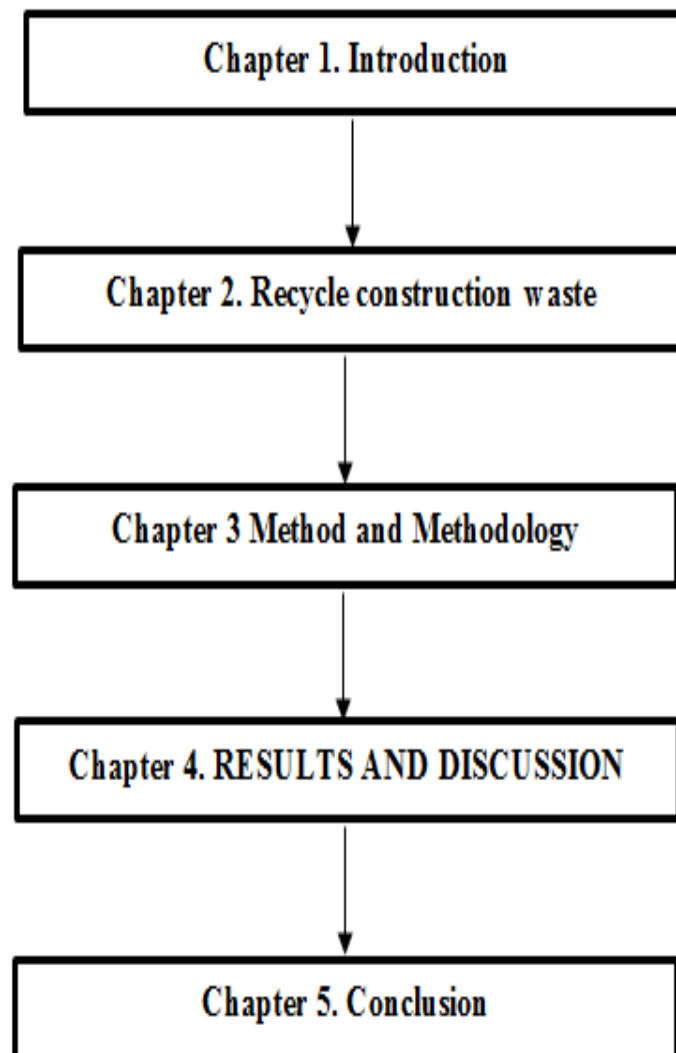


Figure 1.5 Thesis Structure

RECYCLE CONSTRUCTION WASTE

2.1 Introduction

The existing economic models in the sustainable development system have led to environmental problems, resulting in a decline in societal wealth and living standards. In 1989, the Brundtland Report [4] warned that the world's rapidly diminishing natural resources may not be sufficient to meet human needs, potentially halting economic progress and social development. Despite ongoing debates, countries, organizations, businesses, institutions, and employers have come to recognize the imminent danger to the human race. The Brundtland Report [4] introduced the concept of sustainability, which emphasizes meeting present needs and expectations without compromising the rights of future generations. This idea forms the basis of proposed solutions.

In this context, we will highlight the challenges that hinder sustainable development and present our thesis hypothesis along with research goals and questions. To promote sustainable construction practices, we will emphasize the significance of incorporating a scientometric study of material recycling.

Environmental sustainability and environmental economics have been significant areas of research since the late 1970s. Numerous studies and research have been devoted to the idea of environmental sustainable development (ESD), as any activities involving natural resources and the emission of greenhouse gases from fossil fuel combustion contribute to environmental damage [6],[8].

2.2 Academic Research

In the construction industry, the choice of materials has a significant impact on the energy consumed during construction operations. The manufacturing and use of these materials require substantial amounts of energy. However, there is an opportunity to address this issue by recycling construction waste, which can result

in the creation of new products that conserve natural resources and save energy. Additionally, disposing of construction waste through methods such as burning or burying has been shown to have detrimental effects on the environment. The burning process releases toxic gases that contribute to global warming and the depletion of the ozone layer. Therefore, by reducing energy intensity in material operations and manufacturing processes through technological advancements, we can work towards achieving sustainable construction practices [51].

Construction waste is diverse and encompasses materials such as plastic, rubber, rubble, cork, glass, and concrete. Concrete, being a prevalent construction waste, indeed involves significant energy consumption during its manufacturing process. Additionally, when concrete is extensively used in projects, it accounts for approximately 99% of gas emissions and thermal emissions. In contrast, wood and ceramics contribute 14% and 15%, respectively, to thermal emissions, as indicated by a study conducted on buildings in Scotland referenced as [52]. This study highlights the substantial utilization of wood, gypsum, and ceramics in constructing buildings.

Therefore, the most important suggestions are always when studying the feasibility of buildings, is the use of materials that are the least expensive in energy consumption, whether in manufacturing or operating processes, as studies indicate that buildings that use concrete as a basic element for construction are the buildings that consume the most energy. With a rate of more than 18% over the rest of the materials combined, the total life cycle energy consumption of a concrete structure and a super thermal insulation structure is lower than that of a light structure by 5% and 31%, respectively [53].

2.2.1 Criteria for Selecting Environment-Friendly Building Materials

There is a lack of a consistent definition for "sustainable construction materials," despite various studies addressing the issue of material selection. As indicated by reference [54], sustainable building materials can be defined as materials that demonstrate resource and energy efficiency during their production process. Additionally, these materials should have minimal pollution emissions and not

pose any negative impacts on human health. To aid decision makers in evaluating sustainable materials, Abeysundara et al. have developed an evaluation matrix that considers environmental, economic, and social factors [55].

2.2.2 Municipal Solid Waste

According to international reports in 2023, the volume of municipal solid waste (MSW) has nearly tripled, reaching over two billion tons annually, compared to 0.6 billion tons in 2002 [56]. Figure 2.1 shows the proportions of waste generated annually [57]. This significant increase has led researchers and scientists to focus on converting waste into geopolymers and promoting reuse. While waste generation rates are higher in high-income countries, these countries have made more progress in waste reduction and advanced recycling methods.

To improve waste management, effective source separation plays a crucial role in simplifying and enhancing composting, anaerobic digestion, and incineration processes. Unfortunately, low- and middle-income countries face challenges due to contamination issues and the high costs associated with large-scale composting facilities. Despite the high organic content in MSW, composting is less common in these nations.

In high-income countries, waste incineration is often supported by energy recovery systems and environmental controls, thanks to their access to resources. However, globally, a significant portion of MSW is still disposed of in landfills or openly dumped [58]. As a result, solid waste management (SWM) contributes to approximately 5% of the world's greenhouse gas (GHG) emissions [59].

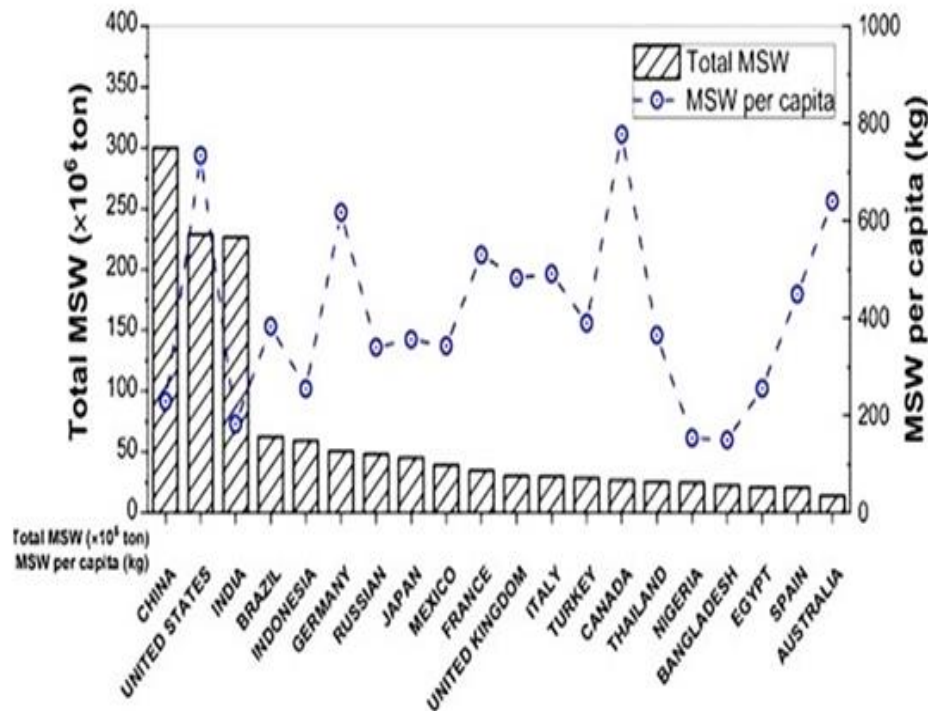


Figure 2.1 Annual MSW generation from selected countries [57]

2.3 The implications of incorporating robust sustainability into business 'literature and practice'

Sustainability is the concept of meeting present needs without compromising the ability of future generations to meet their own needs. When we consider the reference and practical aspects of sustainability for a particular subject, we are already taking the initial steps towards achieving sustainability. The integration of reference sustainability with practical sustainability is crucial in attaining genuine sustainability. This process typically occurs through several parallel phases to maximize effectiveness.

Economic sustainability is an important aspect of overall sustainability. As the market demand and purchase of recycled products increase, economic activity thrives. Environmental sustainability, on the other hand, involves recycling waste instead of resorting to harmful methods like burning or burying it underground. By doing so, we protect the environment and ensure the rights of future generations before those of the current generation.

Reference sustainability serves as the foundation for practical sustainability. Research and studies play a vital role in offering solutions to achieve environmental, economic, and social sustainability. By aiming for integrated sustainability, we can effectively address various aspects and ensure a harmonious balance.

The sustainability of buildings, like any other sector, can be achieved through various means. One of the most significant ways to promote sustainability in this field is through the recycling of concrete and general construction waste. This approach contributes to the overall goal of sustainability in the building sector.

2.4 Sustainable Construction: Challenges and Opportunities

The construction industry has always played a significant role in showcasing the level of development and civilization in different societies and cultures. However, it has also had a considerable impact on the environment. To address this, the industry has been striving towards sustainable practices, and recycling construction waste is a crucial step in achieving this goal.

Traditionally, construction waste has been disposed of through burning or burial, resulting in environmental damage due to emissions of heat and harmful gases. With a growing emphasis on environmental and economic sustainability, the construction industry recognizes the importance of minimizing its ecological footprint.

Recycling construction waste not only helps in preserving the environment but also contributes to social sustainability, a key aspect of sustainable development. The extraction, transportation, and manufacturing processes involved in obtaining raw materials for construction often put a strain on the environment and its resources [60]. Additionally, the disposal of construction waste itself causes environmental pollution, releasing toxic gases and heat.

By recycling construction waste, we can effectively address these challenges. Materials such as glass, plastic, cork, and rubber can be transformed into geopolymer products, reducing the need for new raw materials and minimizing

energy consumption compared to the burning of waste. This approach eliminates toxic gas emissions and thermal pollution associated with traditional disposal methods.

Moreover, waste materials like concrete and soft bricks can be converted into aggregate products that find applications in road construction and the production of ready-mixed concrete. This process of recycling construction waste helps conserve raw materials and reduces energy consumption.

In summary, recycling construction waste is a vital step towards achieving sustainable development in the construction industry. By converting waste materials into usable products, we can save resources, minimize energy consumption, and mitigate environmental damage caused by traditional disposal methods.

2.5 Recycle construction waste

Recycling construction waste is a crucial step in promoting the sustainability of buildings. By recycling these wastes instead of burning or burying them, we contribute to environmental sustainability. Moreover, it helps conserve natural resources for present and future generations, making significant progress towards achieving sustainability goals. Additionally, recycling waste and utilizing it in construction activities as an alternative to materials like cement can contribute to economic sustainability. In Figure 2.2, an analysis of components resulting from building demolitions reveals that approximately 80% of waste consists of organic materials suitable for recycling. Rather than incinerating them, it is preferable to recycle these materials and repurpose them for tasks like road paving. This approach not only minimizes the release of toxic gases associated with demolitions and construction waste but also facilitates the conversion of such waste into non-hazardous compounds like geopolymer. Geopolymer can be utilized as a safe and environmentally-friendly material in various applications [93].

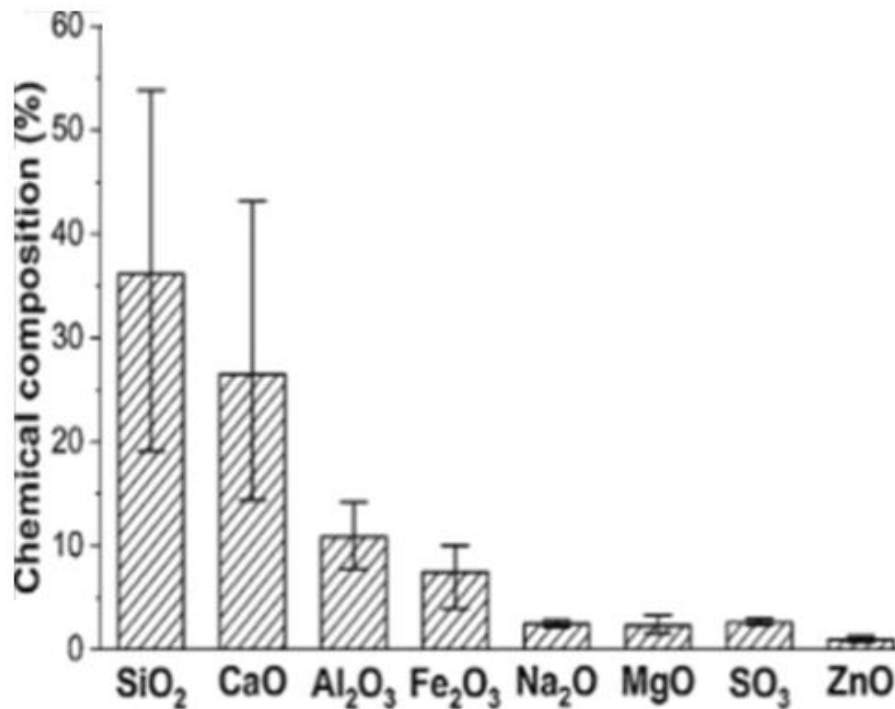


Figure 2.2An analysis of components resulting from the demolition of buildings [51].

2.6 The life cycle of waste recycling.

The majority of building supplies, including concrete, wood, and asphalt shingles, can be recycled at nearby construction and demolition (C&D) recycling sites. These facilities utilize a combination of manual sorting and automated processes involving conveyor belts and sorting machines. These systems effectively separate the materials, which are then sent to other facilities for further processing into new materials that can be reused.

The recycling cycle consists of three main steps, as depicted in Figure 2.3:

- 1) Collection: Recycling materials are gathered from various sources such as curbsides, drop-off locations, deposit/recovery programs, and waste from dumpsters and hauling services.
- 2) Separation: The collected materials are sorted into different groups based on their material type and stored accordingly.

3) Treatment: Each material undergoes specific cleaning and preparation methods to make it suitable for reuse. For instance, plastics are often melted, glass is crushed into smaller pieces, and paper is separated. These processed materials are then sold to different companies for use in manufacturing processes.

Through this recycling cycle, building supplies can be effectively recycled and transformed into new products, reducing the need for extracting and producing virgin materials while promoting sustainability and resource conservation.

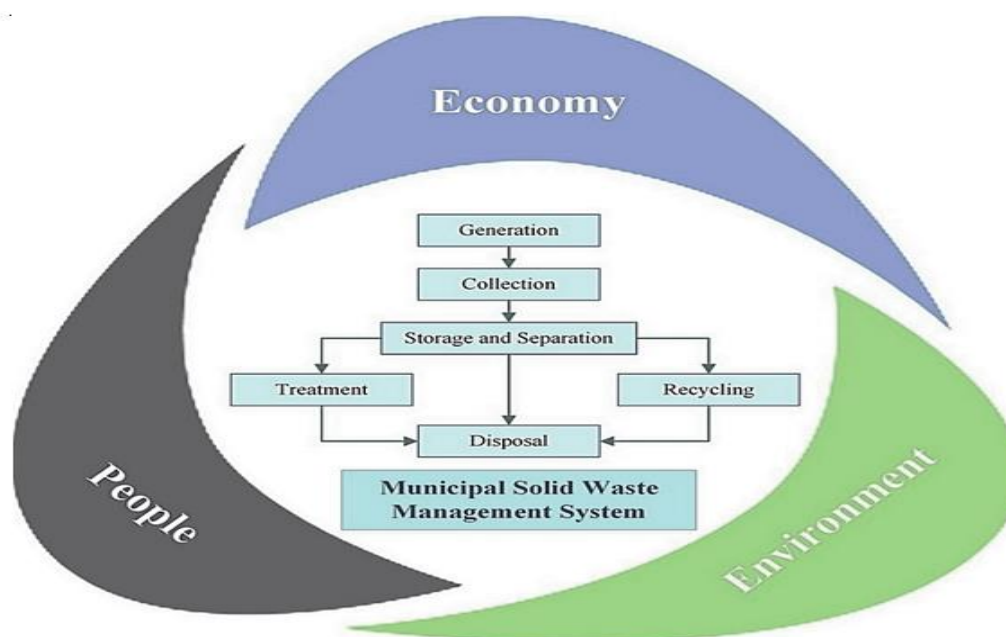


Figure 2.3The life cycle of waste recycling [62]

METHOD AND METHODOLOGY

3.1 Introduction

Scientific research is a multifaceted process that involves various stages, starting with defining the research field and its key questions. Researchers then choose a scientific approach, collect and analyze data, report the results, and subsequently analyze the findings [63],[64]. The evaluation of studies and articles by scientists often relies on metrics like the H-index, which assesses the quality and impact of published work based on citations and references [65]. Scientometric is the field that encompasses these aspects and focuses on measuring and analyzing science, technology, and innovation.

Scientometric analysis is crucial for evaluating the scientific validity of publications, including articles and other types of research outputs. It involves assessing the quality of sources used, examining citation patterns, mapping scientific domains, and developing indicators for policy and management purposes [66],[67],[68]. Figure 3.1 provides an overview of the steps involved in scientometric analysis. Bibliometric analysis, a subset of scientometrics, employs statistical techniques to analyze written publications, such as books and articles [69]. Citation analysis holds particular significance within bibliometric analysis [70].

In this study, we will conduct a scientific analysis of construction waste recycling, specifically employing Scientometric analysis techniques.

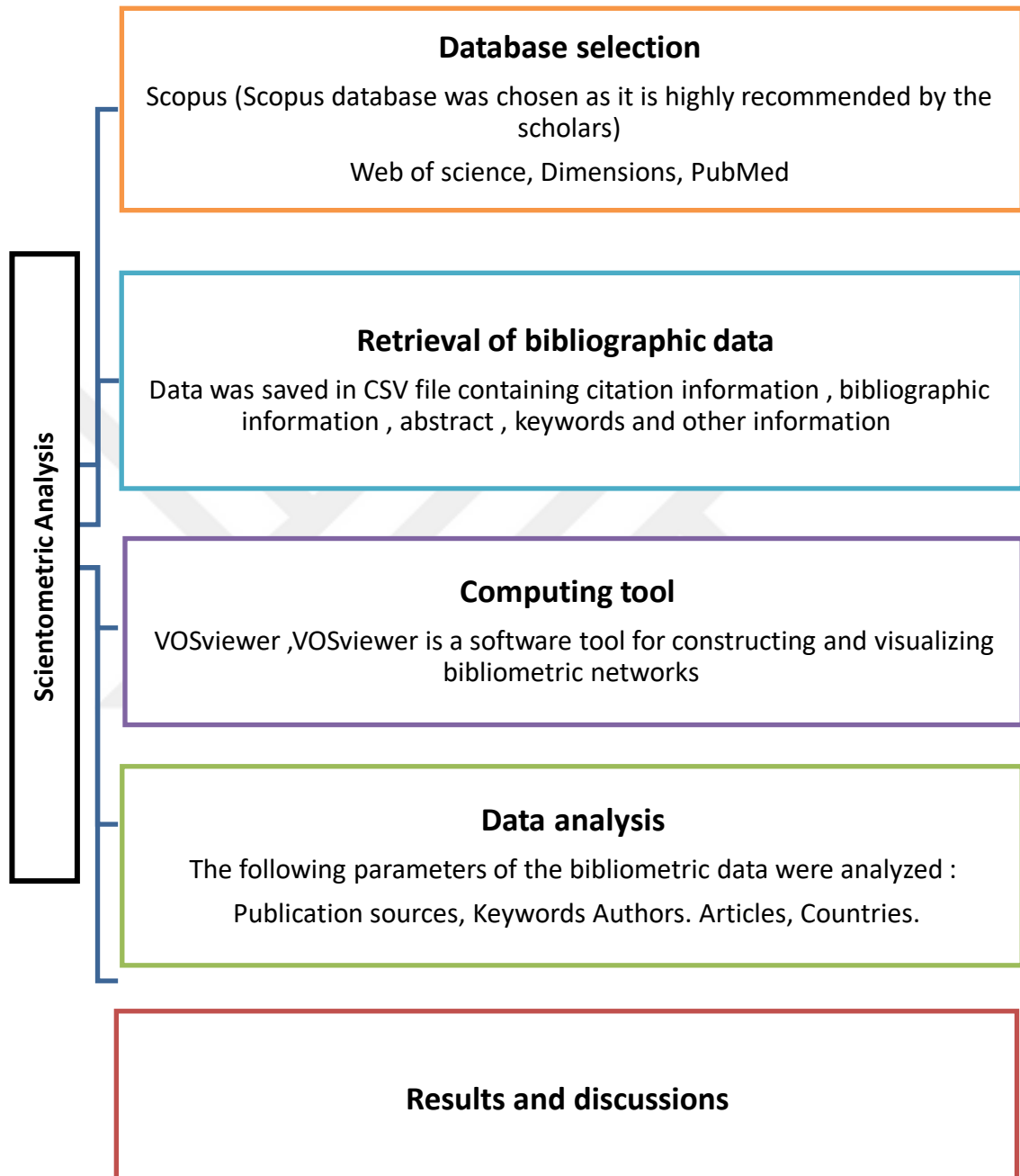


Figure 3.1 Scientometric analysis planner (Research methodology)

3.2 Construction Waste

3.2.1 Concrete

Concrete is the most commonly used building material, accounting for nearly one-third of construction waste. In the past, it was simply disposed of in landfills. However, with the advancement of recycling technology, there has been a growing interest in concrete recycling. This development has not only helped reduce construction costs [71], but also find innovative ways to reuse waste concrete. Initially, it was reused in new concretes based on Ordinary Portland Cement (OPC) [72]. As geopolymer technology has seen significant progress, the focus has shifted towards utilizing waste concrete in geopolymer-based materials and composites [73]. The recycling of concrete and its transformation into geopolymer compounds heavily relies on various factors such as chemical stimulants, curing systems, and replacement ratio. The performance of the geopolymer compounds, which include recycled concrete aggregates, primarily addresses mechanical and physical properties like durability and microstructure. Table (3-1) presents a summary of previous studies that have incorporated waste concrete as aggregates in geopolymer mortar and concrete. These studies involve recycling the concrete and aggregates to create geopolymer compounds, which are then reused. The components are enhanced and chemically treated using alkaline solutions and activation materials [74].

3.2.2 Recycled Aggregate

Industrialization and urbanization have led to a significant increase in infrastructure development, resulting in the generation of large amounts of construction and demolition waste. However, the conventional practice of disposing of this waste in landfills is becoming problematic due to limited landfill space, rising land prices, and escalating waste disposal costs. This issue has become a major concern in affluent nations and a global problem that demands a long-term solution. Additionally, the process of crushing and extracting natural aggregates for construction purposes consumes substantial energy and emits significant amounts of CO₂ [75].

The use of recycled aggregate (RA) in structural concrete offers a possible solution to these environmental and financial problems. Concrete roadbeds, residual concrete, rejected precast pieces, demolished concrete buildings, and tested specimens are a few examples of the materials that are used to make RA [76]. It includes a variety of types, including marble and tile aggregate, asphalt and bitumen aggregate, concrete aggregate, and brick aggregate. Recycled aggregate concrete (RAC) is a type of concrete that uses RAs in place of natural aggregates, either entirely or just a part.

RAC consists of three essential components: aggregates, mortar, and the interfacial transition zone (ITZ) that connects the coarse aggregate, matrix, and mortar [77]. The physical and mechanical properties of the recycled aggregates (RA), the proportion of RA used, the moisture content of the RA, the water-cement ratio (w/c) of the mixture and the resulting matrix's microstructure all influence the compressive, flexural, and split-tensile strength of recycled aggregate concrete.

Utilizing RAC has a number of advantages, including cost savings, reduced energy usage, resource conservation, and a large decrease in waste output. It also promotes ecologically friendly construction methods. This strategy reduces the environmental impact of construction activities while simultaneously addressing the issues caused by constrained landfill space and rising disposal costs. It also supports sustainable development.

3.2.3 Supplementary cementitious materials

The production of cement is a major source of greenhouse gas emissions, which significantly contributes to climate change [55]. However, efforts are being made to mitigate these emissions by incorporating secondary cementitious materials (SCMs) into concrete production. These SCMs consist of various agricultural waste products, such as sugarcane bagasse ash, olive oil ash, corn cob ash, sawdust ash, rice husk ash, and palm oil fuel ash, as well as industrial by-products like fly ash, silica fume, red mud, tailings, coal gangue, and slag. Utilizing these waste materials in concrete helps reduce CO₂ emissions and offers improved mechanical and durability properties for the composites when used as pozzolanic materials.

Proper utilization of these waste materials is crucial as landfilling them poses significant environmental risks, including water and air contamination [39].

3.2.4 Geopolymer Concrete

Geopolymer is an innovative binder currently being developed as a substitute for cement in concrete production. Its primary objective is to create a construction material that is environmentally responsible, sustainable, and does not rely on cement as a binder. The term "Geopolymer" was first coined by Davidovits in 1972, referring to a novel inorganic aluminosilicate polymer with a three-dimensional network structure composed of silicon-oxygen and aluminum-oxygen tetrahedrons linked by bridge oxygen atoms [51],[52]. The term itself combines "geo" to signify silica- and alumina-rich industrial or geological materials like kaolin, Metakaolin, fly ash, ground granulated blast furnace slag, silica fume, waste glass, palm oil fuel ash, and RHA, among others, with "polymer" to signify a series of molecules that are descended from a single molecule.

The utilization of geopolymer concrete derived from waste materials is gaining popularity due to its numerous benefits, including the conservation of natural resources, reduced energy consumption, decreased CO₂ emissions, and improved waste management. Geopolymer production using fly ash, for example, requires approximately 60% less energy compared to cement production and results in at least an 80% reduction in CO₂ emissions. This trend towards geopolymer-based solutions reflects a growing recognition of the need for sustainable construction practices in order to address environmental concerns effectively.

3.2.5 Rubber waste

Recycling rubber waste has become a crucial global environmental mission due to its extremely slow decomposition rate [75]. In the past, burying rubber waste underground was the conventional method of disposal, but now the urgency to recycle it has heightened. A common recycling approach involves grinding shredded tire pieces into granules of specific sizes, which are then utilized in geopolymer compounds. Figure 3.2 depicts the chemical composition of rubber. Since rubber waste is challenging to decompose and burning it poses significant

environmental harm, recycling has emerged as an essential process for environmental preservation [76].

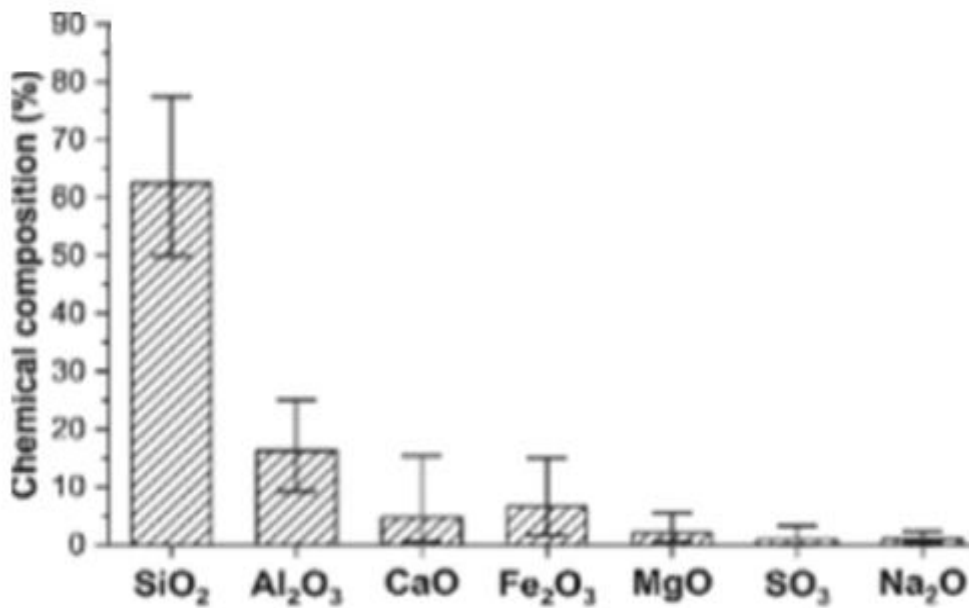


Figure 3.2 Chemical analysis of Rubber [51]

3.2.6 Waste glass

Approximately 5% of the global glass waste is currently recycled [77]. However, the recycling rate for glass is only 13% [78]. The chemical composition and mineralogy of glass, particularly its high silicon content, make it suitable for conversion into a geopolymer. In 2019, the recycling rate increased to 13% due to the reactivity of glass, which contains significant amounts of amorphous silicon and calcium. Extensive research has been conducted to explore the use of waste glass in the production of geopolymer composites. Besides, waste glass can also be reused as aggregates [79], as indicated in the context of geopolymers [80].

The chemical composition of glass waste is depicted in Figure 3.3. Recycling glass waste is a straightforward and uncomplicated process, involving the crushing of glass and subsequent re-melting to produce various types of glass.

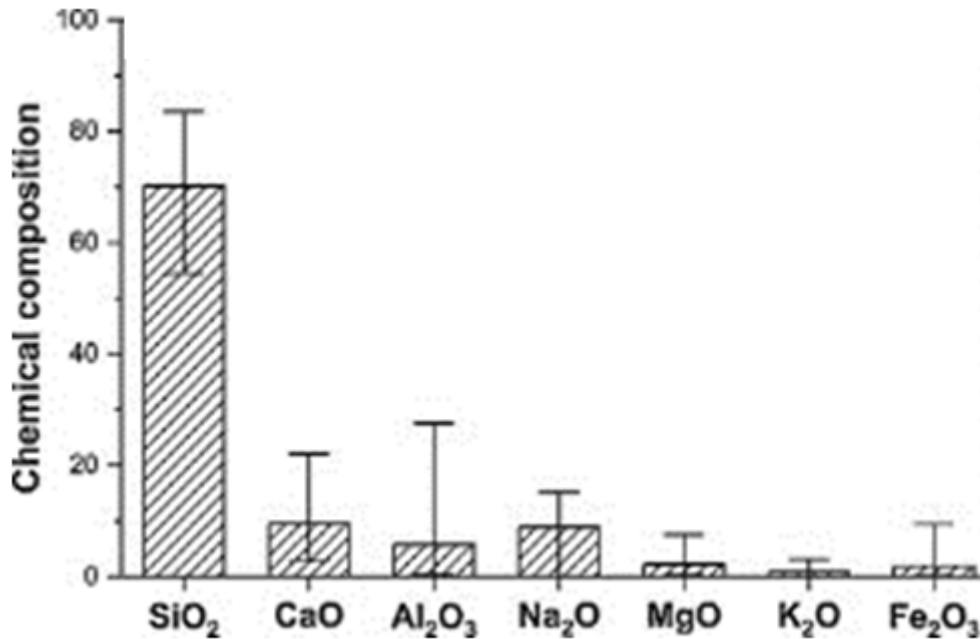


Figure 3.3 Chemical analysis of glass waste [51]

3.2.7 Waste cork

Cork, known for its high carbon content, underwent its first recycling process in 1980, involving the repurposing of discarded wine bottles. In a study conducted by [81], cork was recycled using a heat treatment method. This involved subjecting the cork to temperatures as high as 900 degrees Celsius in granite ovens, followed by cooling with nitrogen to produce a powder with a particle size smaller than 75 μm . By adding 2.5% to 3.75% pyrolysis, the decomposed cork was directly incorporated into geopolymer composites. The substantial carbon content (90.74 wt. %) of the decomposed cork made it an effective carbonator, serving as a source for electromagnetic interfacial reinforcement and exhibiting preferable shielding properties in the geopolymer composites.

3.2.8 Waste clay brick

Clay brick (WCB) is a commonly used building material, second only to concrete. Waste from clay bricks is generated not only during demolition operations but also from brick factory remnants, fractured bricks, and those that do not meet specifications. Recent studies have shown that WCB can be a viable substitute

material for geopolymer composites [82]. To enhance its performance, researchers have explored various improvements in the formation of WCB-based geopolymers using alkaline solution activation. These improvements involve parameters such as the type of alkaline solution, silica ratio, and alkalinity concentration [83],[84]. For instance, [85] examined the impact of alkaline concentration (4-10%), silica ratio (0-2.2), curing temperature (50-90°C), and processing time (1-7 days) on the stability and strength of WCB-based geopolymer mortar.

3.2.9 Waste Plastic Materials

Plastic materials have a significantly long decomposition time [86]. In the past, the common method of disposing of plastic waste was burying it underground. However, the urgent need for environmental sustainability has made recycling plastic materials a worldwide priority[87]. One approach involves grinding shredded tire pieces into granules of specific sizes, which are then utilized in geopolymer compounds.

3.2.10 Paper Waste

The use of raw waste paper in construction materials is not very common. Instead, a significant amount of waste paper is recycled into new paper products, which helps to save wood and other forest resources and has a lower environmental impact. However, the process of converting recycled paper into usable fiber for papermaking often produces a byproduct known as waste paper sludge. This sludge has a high moisture content, typically ranging from 50% to 70%, and is usually dried before further processing, such as handling, incineration, or potential applications.

Waste paper sludge consists of roughly equal proportions of organic materials, mainly residual cellulose fiber, and inorganic fillers, including kaolin clay and calcium carbonate [58]. Previous research has primarily focused on using waste paper sludge in construction materials based on Ordinary Portland Cement (OPC).

However, the idea of incorporating waste paper sludge into geopolymer composites is a relatively new concept [59].

Studies on the use of waste paper sludge in geopolymer composites have revealed two main approaches. In a chemical study, waste paper sludge has shown compatibility with geopolymer chemistry, suggesting its potential as an additional ingredient in geopolymer composites. Consequently, the first strategy involves using the unprocessed waste paper sludge [87]. Researchers have investigated the properties of geopolymer mortar containing 2.5-10% dry waste paper sludge by weight of the total precursor. The results indicate that the inclusion of waste paper sludge in geopolymer mortar reduces workability by 11-33% and compressive strength by 8-42%. However, even with these reductions, the compressive strength remains above 31.2 MPa.

3.3. Methods

3.3.1 Most productive research articles

According to the Scopus database, a search using keywords such as "sustainable construction," "recycling," "recycled," "green buildings," and "waste materials" yielded a total of 946 articles from 2010 to 2023. After conducting a manual sorting process, it was found that approximately 499 of these articles focused on recycling materials in sustainable construction or the utilization of construction waste for the production of sustainable materials. Table 3.1 displays the top fifteen articles that were both highly productive and cited throughout the research period.

Table 3.1 Top 15 articles with highest citations.

S/N	Article title	Author	Citation	Year	Link
1	“Development of sustainable construction material using industrial and agricultural solid waste: A review of waste-create bricks” [88]	S.P. Raut ^a , R. Ralegaonkar.	294	2011	9
2	“Short and long-term behavior of structural concrete with recycled concrete aggregate” [89]	Manzi, S. Mazzotti,C.	223	2013	7
3	“Sustainability: A new imperative in contaminated land remediation” [90]	Hou,D.	206	2014	6
4	“Pathways to circular construction: An integrated management of construction and demolition waste for resource recovery” [91]	Ghaffar, S.H. Burman, M.	159	2020	5
5	“Compressive and flexural behaviours of a new steel-fibre-reinforced recycled aggregate concrete with crumb rubber” [92]	Xie, J.-H. L.-S., Xie, Z.-H	145	2015	4
6	“Measuring the impact of prefabrication on construction waste reduction: An empirical study in China” [93]	Li, Z., Shen, G.Q.	138	2014	4

Table 3.1 Top 15 articles with highest citations (continued...)

7	“Closed-loop recycling of recycled concrete aggregates” [94]	Marie, I. Quiasrawi, H.	138	2012	4
8	“Rank of green building material criteria based on the three pillars of sustainability using the hybrid multi criteria decision-making method” .[95]	Khoshnava, S.M. Rostami, R	119	2018	3
9	“Utilization of unbound recycled aggregates from selected CDW in unpaved rural roads” [96]	Jiménez, J.R.	116	2016	3
10	“Use of Recycled Construction and Demolition Waste Aggregate for Road Course Surfacing” [97]	Herrador, R. Pérez, P.	112	2011	3
11	“Advanced progress in recycling municipal and construction solid wastes for manufacturing sustainable construction materials” [98]	Tang, Z.	109	2020	3
12	“Maximum feasible use of recycled sand from construction and demolition waste for eco-mortar production - Part-I: Ceramic masonry waste” [99]	Ledesma, E. Jiménez, J.R.	107	2015	3
13	“Life Cycle Assessment (LCA) of different kinds of concrete containing waste for sustainable construction” .[100]	ColangeloF . Forcina, A	104	2018	3

Table 3.1 Top 15 articles with highest citations (continued...)

14	“Eco-efficient waste glass recycling: Integrated waste management and green product development through LCA” [101]	Blengini, G.A. Fantoni, M	97	2012	3
15	“Effective utilization and recycling of mixed recycled aggregates for a greener environment” [102]	Zhang, L.W. Sojobi, A.O.	96	2019	2

Map 3.1 show articles with highest citations. During the search period, for that analysis, the articles and the author's name was chosen as the (kind of analysis) and (Citations) was chosen as the (unit of analysis) in VOS viewer.

3.3.2 The Number of Articles

According to the research field and keywords, 946 articles were published . Table 3.2 shows the number of articles related to sustainable construction, green building, and recycling material after filtering and sorting manually. Figure 4.3 shows their classification according to the most important topics.

Table 3.2 Documents searched in Scopus database until June 2023

S/N	Searched keyword	Document	Document after filters
1	Sustainable construction	946	499
2	Green building		
3	Recycling material		

Table 3-2 provides information on the number of articles and their total citation rates for each year, sorted by the duration of the search. The year 2022 emerged as the most productive in terms of articles related to the research subject, and it also received the highest number of citations. On the other hand, 2013 was the least productive year in terms of article output, while 2010 received the least citations among the articles published during that year.

Table 3.3 Number of articles per year and Total Citations

YEAR	No. of Article	Total Citations
2023	59	26
2022	94	481
2021	80	869
2020	49	1,080
2019	33	716
2018	27	753
2017	28	753
2016	22	639
2015	24	615
2014	28	1,047
2013	14	486
2012	17	697
2011	13	616
2010	11	196

3.3.3 Top Contributing Countries

Scientometric analysis showed varying levels of contributions from different countries in the field of research and the period specified for the research investigation. In order to facilitate the visualization of the analysis of the countries that produced the most articles, visualization networks were created, where the unit of analysis in these networks was (countries), and the type of analysis was (bibliographic coupling).

Table 3.4 present the countries that display the highest level of activity in terms of the quantity of records and citations connected to the current area of study. With 74 documents, China emerged as the top provider, followed by the US with 55 documents and India 53 documents. Referring to figure (2-1) shows the volume of annual production of municipal solid waste (MSW) in most countries. We note from this that the countries that produce the most municipal solid waste have primarily sought to adopt the principle of recycling and optimal exploitation of that waste instead of following traditional methods of burning or burying it. which has helped contribute to sustainable development and achieve environmental, economic, and social benefits that have limited pollution to the environment and the consumption of raw materials.

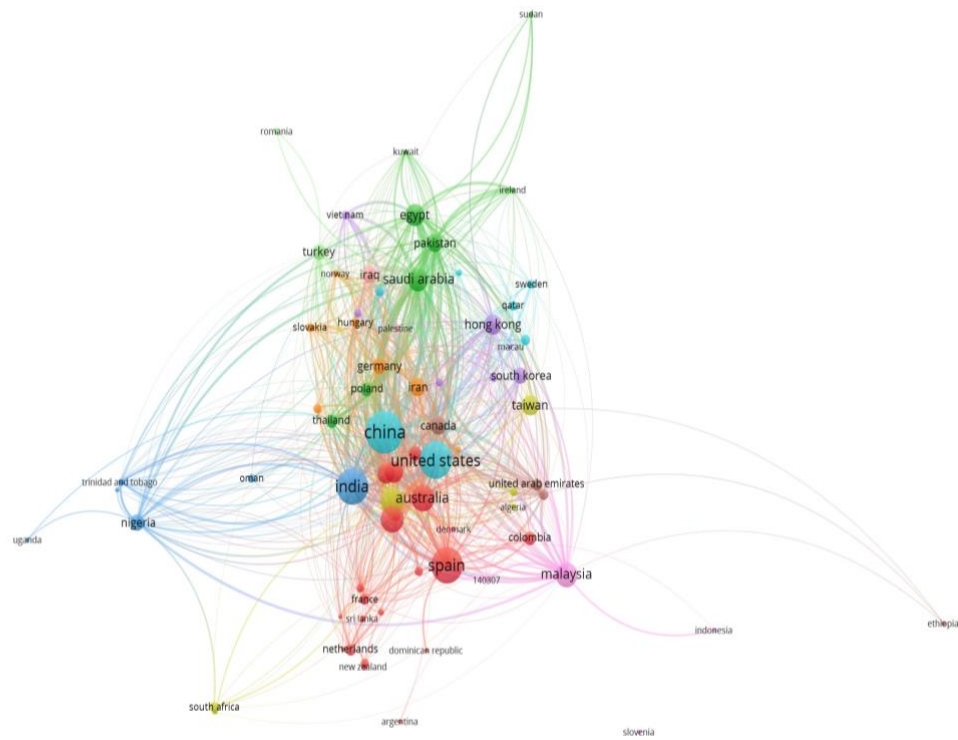
The visual map (3.2) indicate the countries that produce the most articles are in blue, followed by the countries that produce the least in red, green, and yellow in order of decreasing production. China, the United States, and India were at the forefront of countries producing articles and studies to develop successful plans in the field of sustainability and recycling.

The visual maps also showed the volume of cooperation and citations between authors in the countries, and this indicates the volume of substitution of scientific benefit and the significance of the research topic for most authors.

Table 3.4 Top 15 most contributing countries in the relevant field

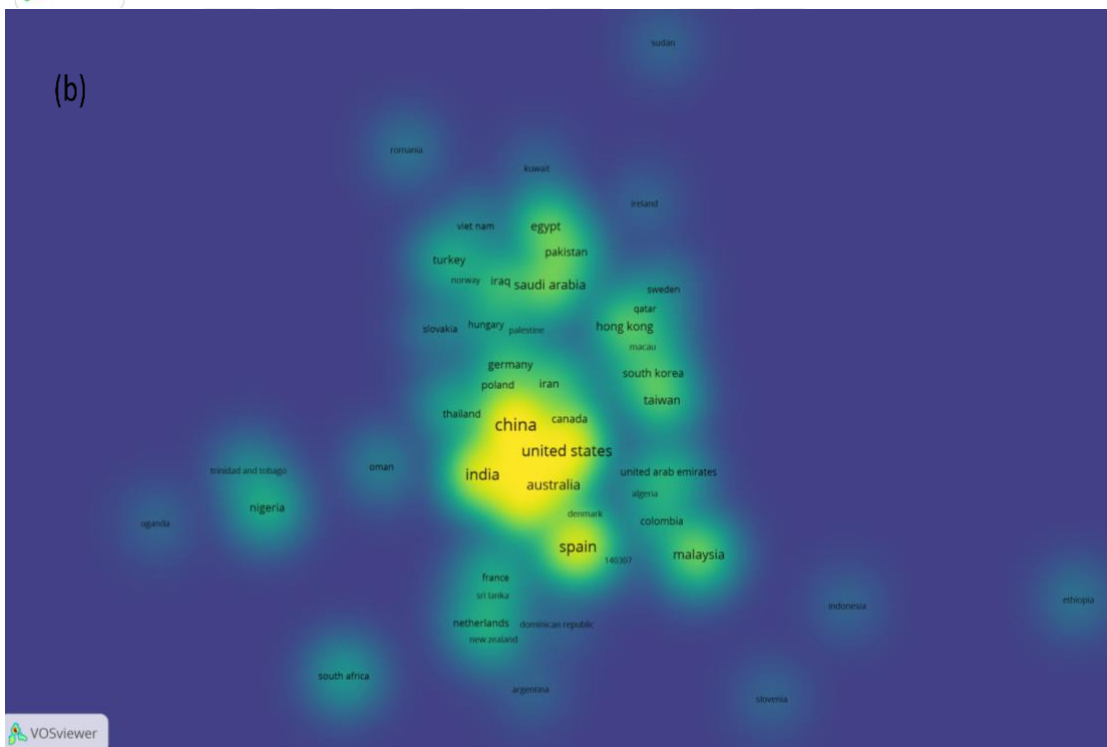
S/N	Country	NO. of Documents	NO. of Citations
1	China	74	1,280
2	United States	55	1,250
3	India	53	906
4	Spain	52	1,180
5	Australia	30	637
6	United Kingdom	28	1,089
7	Italy	28	694
8	Malaysia	27	352
9	Brazil	18	258
10	Hong Kong	17	813
11	Taiwan	16	201
12	Canada	14	199
13	South Korea	11	184
14	Turkey	10	180
15	Japan	3	50

(a)



VOSviewer

(b)



VOSviewer

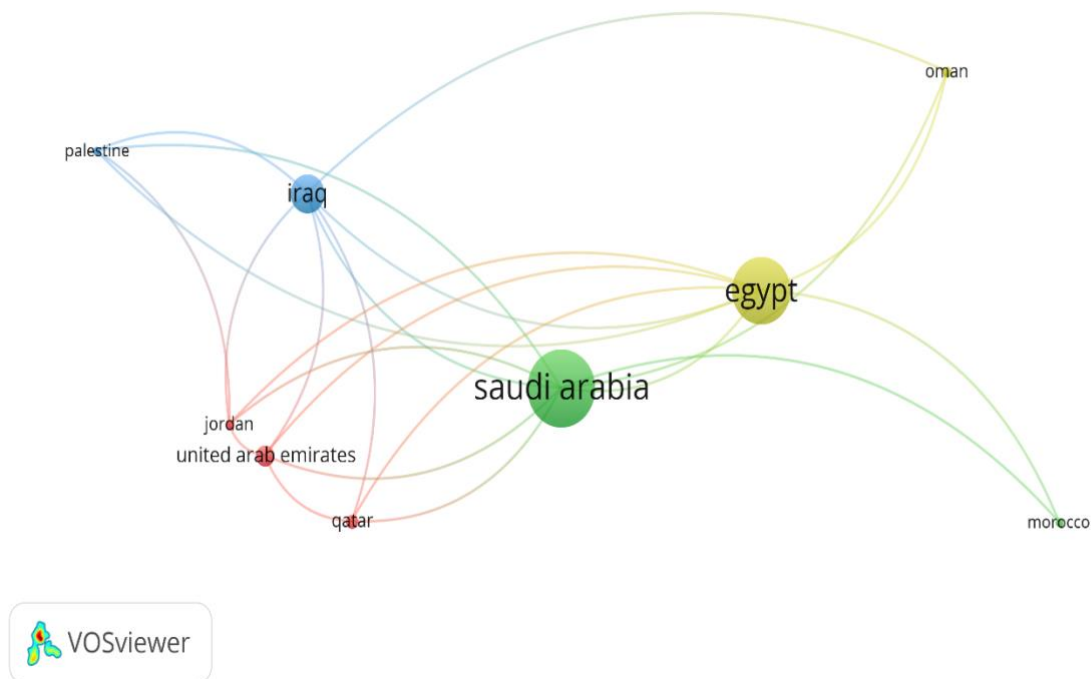
Map 3.2 The Network Visualization and Density Visualization of most contributing countries in the relevant field, (a): Network Visualization MAP & (b): Density Visualization Map.

3.3.4 Contributing Countries

During the last two decades, Arab countries have witnessed remarkable interest in the field of sustainability and recycling of materials, despite the lack of articles contributing in this field, which reflects the beginning of a change in the policy of construction and in sustainable development. Table 3.5 and map 3.3 shows the contributions of Arab countries from articles within the scope and duration of the research.

Table 3.5 Contributing Arab countries in the relevant field

S/N	Country	Documents	Citations
1	Saudi Arabia	22	283
2	Egypt	19	293
3	Iraq	11	299
4	United Arab Emirates	6	24
5	Qatar	4	46
6	Oman	3	13
7	Jordan	3	153
8	Sudan	1	11
9	Kuwait	1	10
10	Palestine	1	10



Map 3.3 A Network Visualization map for Arab countries contribute to the relevant field

3.3.5 Most common keywords

Keywords play a crucial role in research as they define and represent the core subject area of a study [77]. An analysis was conducted on 170 research papers published between 2010 and 2023, focusing on the keywords used. Table 3.1 presents the fifteen most commonly used keywords, with "recycling" and "sustainable construction" emerging as the primary and frequently searched terms in the field of sustainability and recycling. Other keywords not listed in the table were searched less than twenty times, hence only the top fifteen keywords are mentioned. Table 3.6 is a list of the top 15 frequently used keywords in research articles related to the current field of research.

Table 3.6 Top Keywords with the most citation bursts

S/N	Keyword	Occurrences	Strength Link
1	Recycling	241	1,413
2	Sustainable Construction	190	1,133
3	Sustainable Development	183	1,132
4	Compressive Strength	109	711
5	Sustainability	89	455
6	Concrete Aggregates	83	640
7	Aggregates	59	462
8	Waste management	56	354
9	Demolition	54	397
10	Concrete	51	386
11	Concretes	49	49
12	Fly Ash	48	330
13	Durability	41	289
14	Concrete mixtures	36	294
15	Tensile strength	33	246

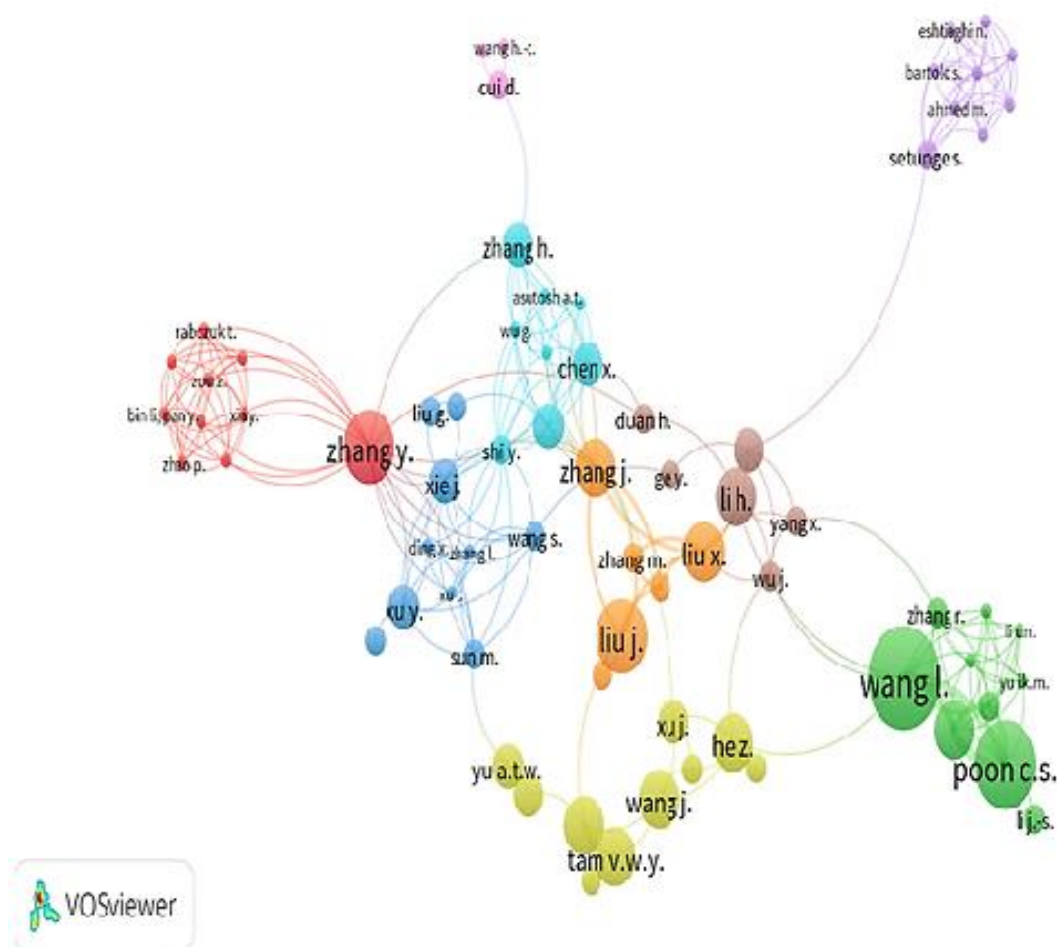
authorship.. By utilizing data from the Scopus database, Table 3.7 presents the top authors in the field with the highest number of articles and citations.

Table 3.7 Top 15 contributing authors

S/N	Author	Documents	Citations	Total link strength
1	Poon, C.S.	7	274	8
2	Auso,j.	6	138	5
3	Pérez, I.	6	125	5
4	Pasandín, A.R.	5	125	5
5	del Río Merino, M.	5	99	0
6	Liu,J.	5	34	5
7	Raut, S.P.	4	300	0
8	Tsang, D.C.W.	4	194	8
9	Wang, L.	4	194	4
10	De brito j.	4	147	1
11	Galvín, A.P.	4	131	4
12	Tam, V.W.Y.	4	120	4

Table 3.7 Top 15 contributing authors (continued...)

13	Li h.	4	106	2
14	Wang, j.	4	91	3
15	He,z.	4	54	2



Map 3.5 Science network visualization map for Co-authorship

3.3.7 Top Publication Sources

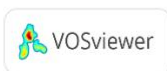
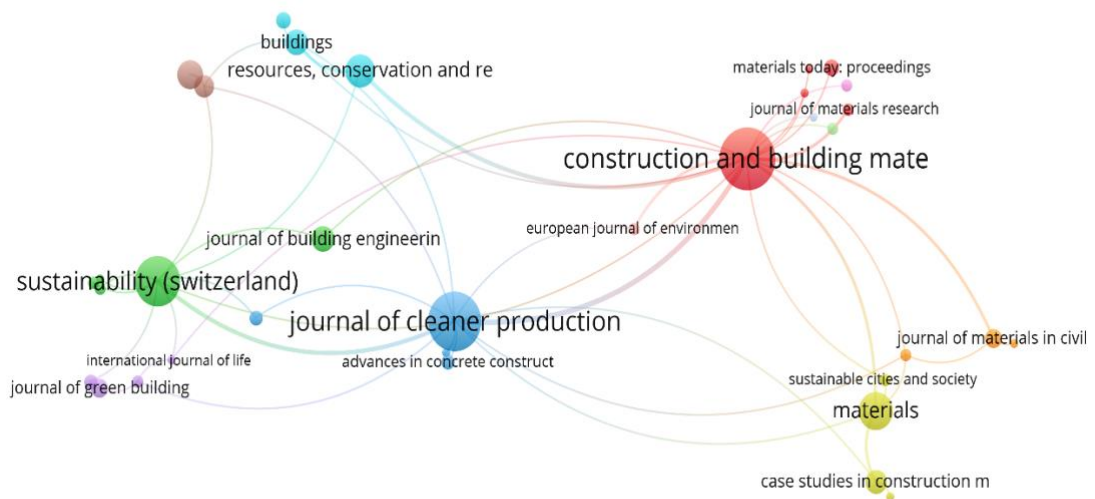
Source mapping provides access to limited data within predetermined limitations, enabling the investigation of innovation and progress. A sequential research pattern can be applied to the analysis region by starting with the mapping of sources. The VOS viewer was used in this investigation, which made use of Scopus bibliometric data. The analysis unit was selected as the source, and the analysis method that was used was bibliographic coupling. Table 3-8 presents the leading sources/journals that published articles containing data on sustainability and the implementation of recycled resources in concrete, coupled with the number of citations and the strength of all the links.

Table 3.8 List of publication sources with a number of articles

S/N	Source	Document	Citation	Link
1	Construction and building materials	44	1,524	23
2	Journal of cleaner production	40	1,810	16
3	Sustainability (Switzerland)	31	333	11
4	Materials	19	125	7
5	Buildings	10	178	6
6	Resources , conservation and recycling	15	773	6
7	Journal of building engineering	10	57	2
8	Case studies in construction materials	9	194	3

Table 3.8 List of publication sources with a number of articles (continued...)

9	Waste management	7	211	7
10	Journal of materials in civil engineering	6	104	3
11	Journal of green building	6	102	2
12	Energy and buildings	4	129	2
13	Cement and concrete composites	3	229	4
14	European journal of environmental	3	132	3
15	Environment, development and sustainability	3	145	2



Map 3.6 Science network visualization map for source

RESULTS AND DISCUSSION

4.1 Introduction

Scientometrics is the field that involves the measurement and analysis of science [88], technology, and innovation. It focuses on assessing the impact of research by examining references or a collection of articles [87]. Scientometrics aims to understand scientific citations, map scientific disciplines, and generate indicators that can be used in policy-making and management [76]. Figure (4-1) illustrates the various steps involved in scientometric analysis [96].

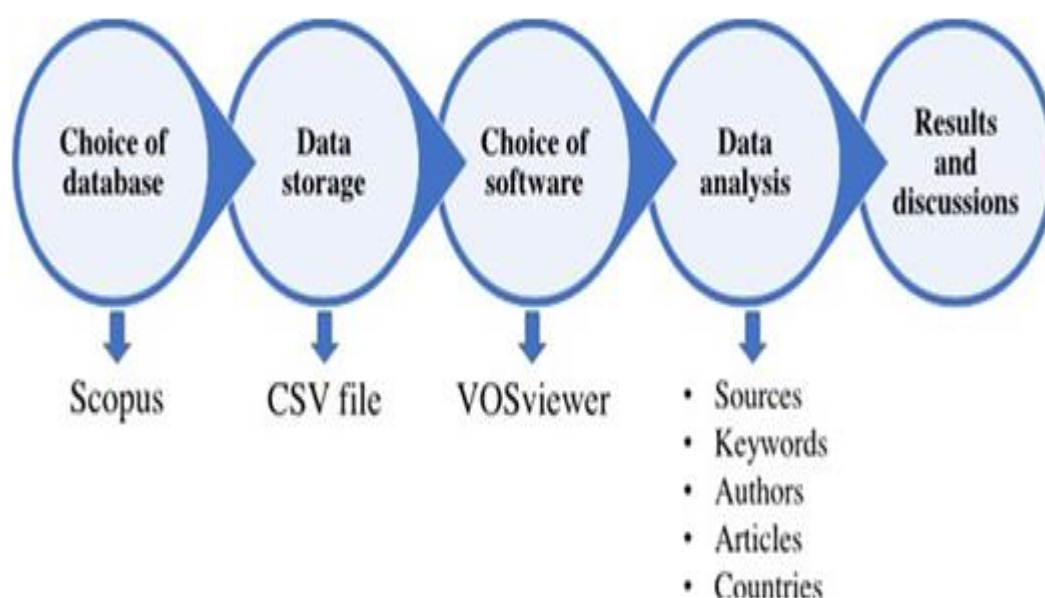


Figure 4.1 Sequence followed for scientometric analyze [96]

4.2 Documents searched in Scopus database

Table 3-1 displays the results of a research study conducted using the Scopes database. The study aimed to explore relevant articles published between 2010 and February 2023 as shown in Figure 4.2, focusing on sustainable construction, green

buildings, Material recycling, and waste. Several data refinement options were employed to ensure the selection of only pertinent articles, specifically filtering by document type, The subject areas of engineering, material science, and environmental science. The resulting document was saved as CSF file to analyze data.

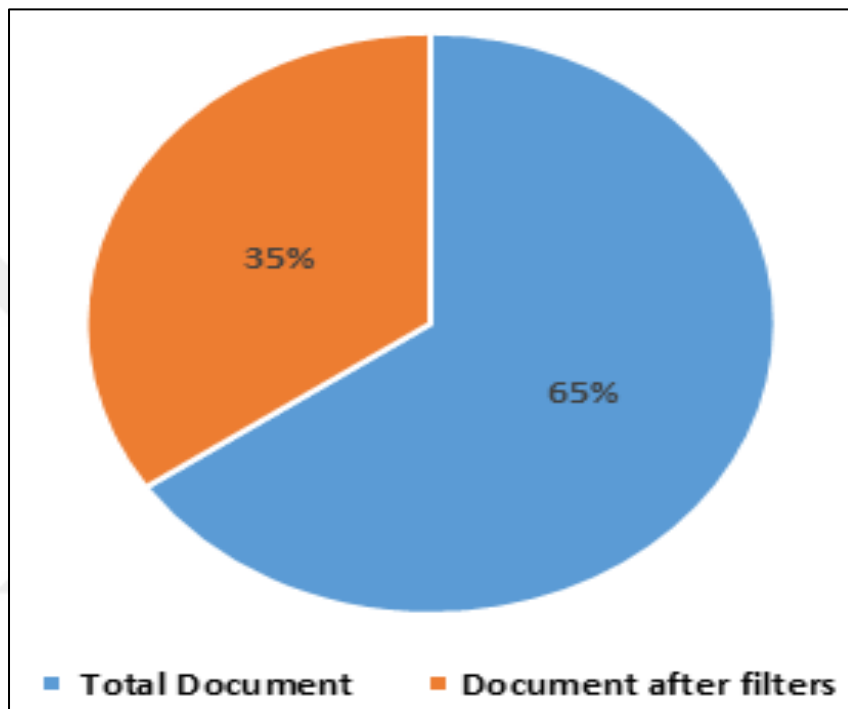


Figure 4.2 Document results before/ after applying filters

In the field of research, 499 articles stretching a range of subjects pertaining to waste recycling and sustainable construction were published. The following resulted after manually categorizing the articles in search of more information about the research topics: 91 articles focused on recycling materials in sustainable construction, and 72 articles related to recycling aggregate. 57 articles investigating the recycling of waste, with a special focus on waste tires, plastic, glass, cork, fibers, clay bricks, and rubber.

Over the research period, 50 articles were published on the topic of sustainable development, while 46 articles focused on aggregate recycling. Geopolymer concrete and geopolymer composites are also of clear importance to researchers so 43 articles were published about them, and 40 articles focused on green building practices, 36 articles on waste management in construction, and 38 articles on the economic significance of cementitious materials as an alternative to ordinary Portland cement (OPS) were published. Finally, green concrete was the topic of 26 articles. as shown in Figure 4.3 in a visual representation of the distribution.

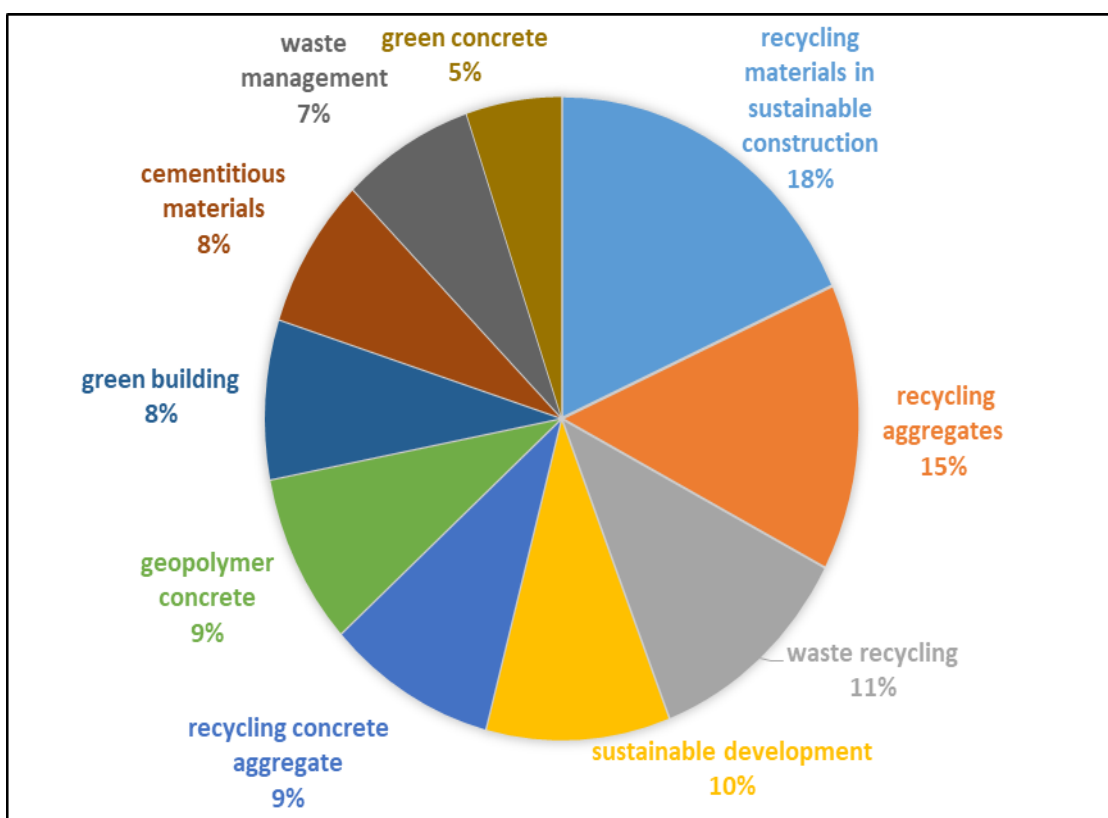


Figure 4.3 Classifying articles according to keywords within the scope of the search

4.3 Annual Publication Trend

The annual publication trend from 2010 to 2023 is shown in Table 3-3. The number of articles is shown by the blue line in Figure 4.4, while the number of citations is represented by the red line. Notably, despite having fewer articles published, 2020 stands out as the year with the largest number of citations. In the area of sustainability, this trend is especially noticeable. Additionally, the years 2021 and 2022 can be defined as a time when article output significantly increases.

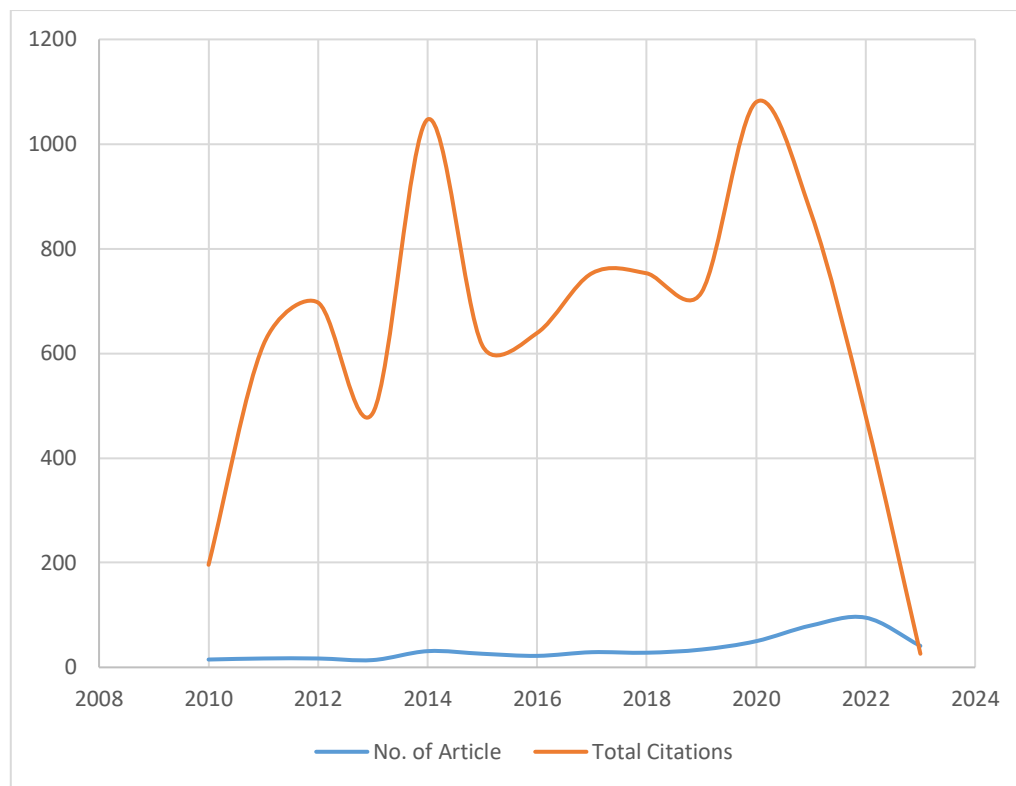


Figure 4.4 Annual publication trend of articles

4.4 Top Keywords with the most citation bursts

Table 3-6 present data on the percentages of search keywords, including terms like recycling, building materials, cement, concrete, silicate, and more. Interestingly, we observe that approximately 68% of the search words are related to recycling materials and concrete (as show in Figure 4.5).

Upon analyzing this trend, it becomes evident that there is a logical correlation because cement concrete makes up over 70% of construction waste.

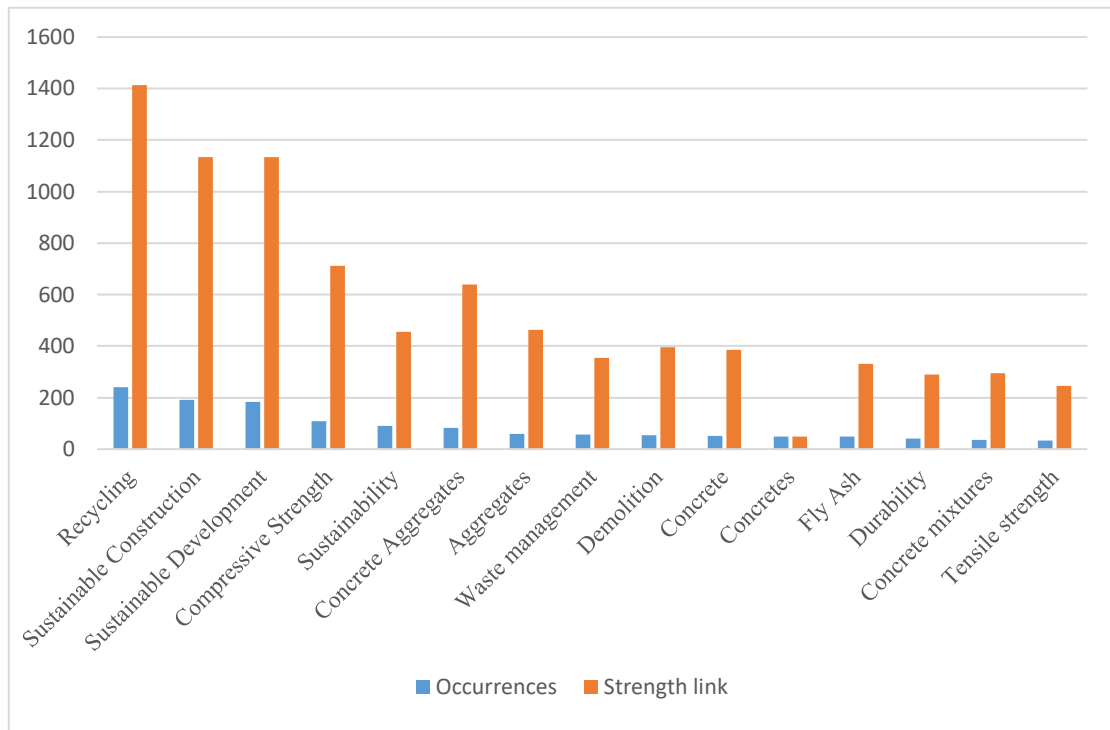


Figure 4.5 The percentage of search words

4.5 Productive Countries in Construction Waste Management Studies

Some countries are more actively involved in current research in the field, while others contribute less. In many nations, the responsibility for managing solid waste falls on the local level. However, low- and middle-income countries encounter difficulties in implementing sustainable waste management methods due to limited funding, capacity, and resources from local governments, as well as inadequate enforcement of relevant legislation. In contrast, higher-income countries take the lead in adopting sustainable waste management practices. Among these practices, the strategy of source reduction is the most widely adopted technique within the sustainable waste management hierarchy.

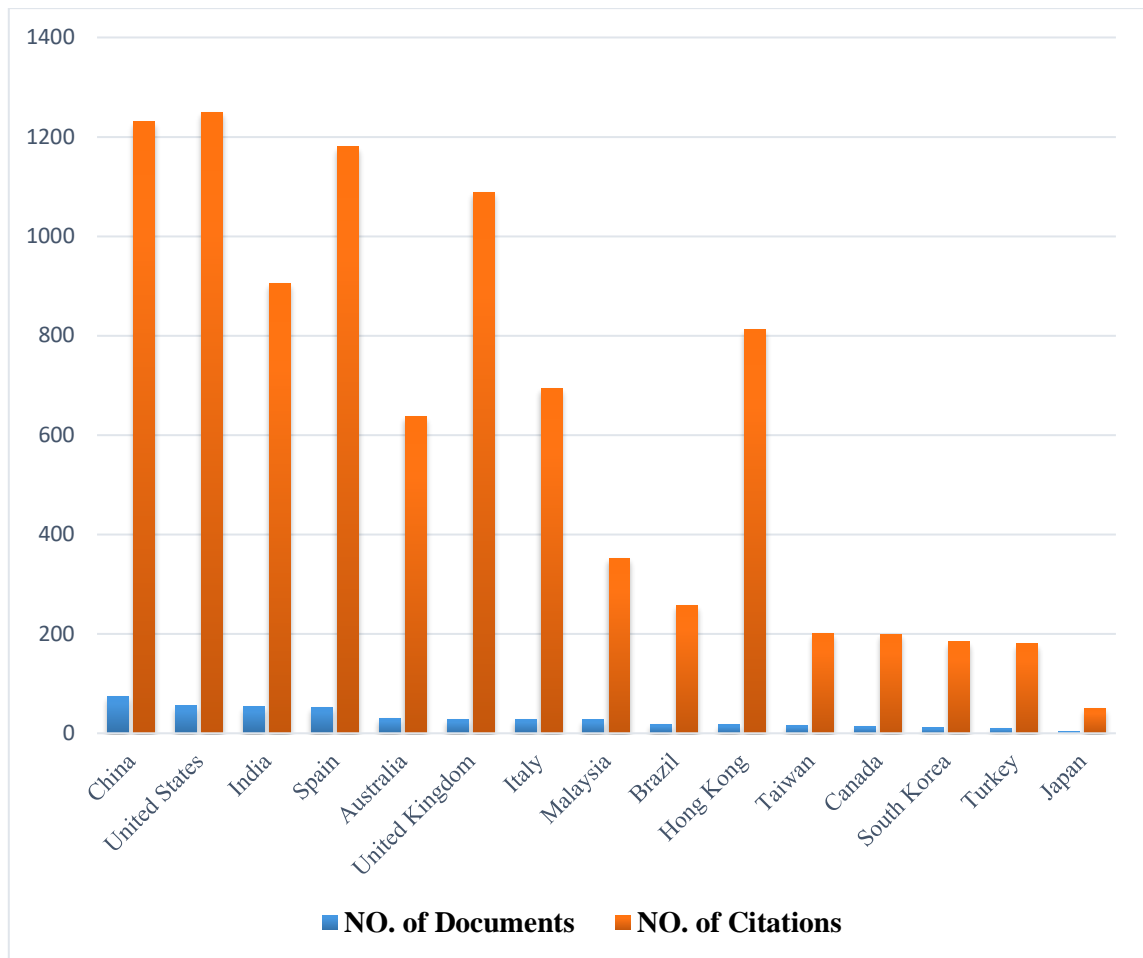


Figure 4.6 Top contributing countries

According to the data presented in Table 3-4 and Figure 4.6, it is evident that China, India, the United States, Spain, and Australia are the leading countries in terms of article production. Out of 499 articles, 436 articles were published in the first fifteen countries. This represents nearly 87% of all articles published between 2010 and mid-2023.

The analysis of the quantity of documents, citations, and linkages displayed in Maps 3.2a and 3.2b provides insightful information about the impact of various nations on the research area. The impact of a country's papers on other nations in that field can be assessed by the total link strength. The results show that China is the leader with a total link strength of 1,280, closely followed by the USA with 1,250 and Spain with 1,180.

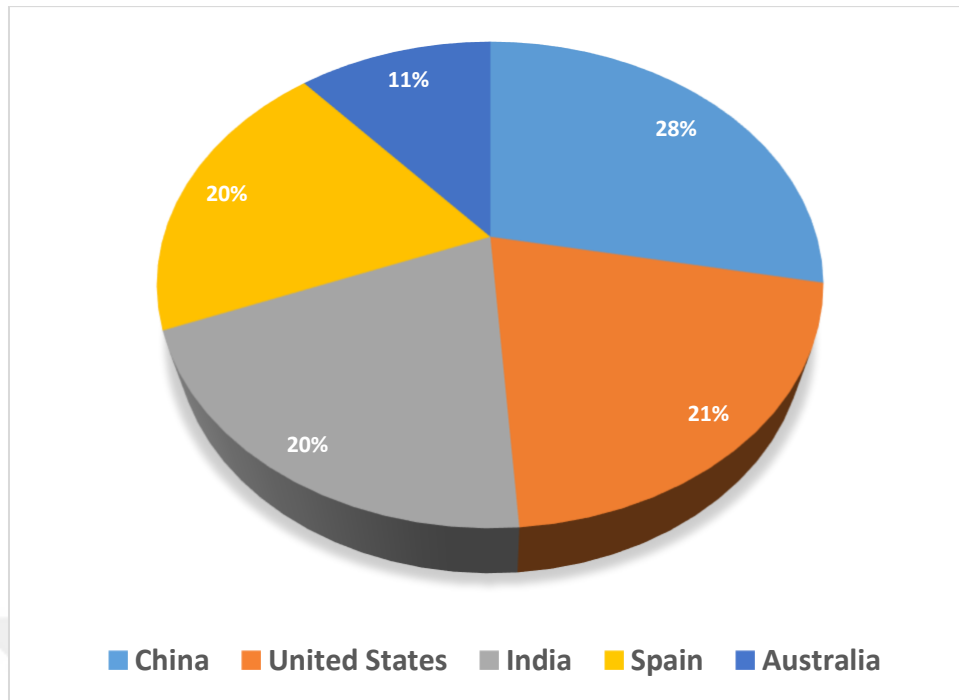


Figure 4.7 Top five countries in the number of publications

Environmental pollution poses a significant challenge for numerous countries, including Arab nations. Despite experiencing continuous and robust economic growth, particularly among oil-rich countries, many Arab nations struggle with the depletion of natural resources and climate pollution. This stems from their inadequate consideration of environmental concerns in various industrial activities, notably oil and gas refining. Consequently, the development of clean technology has become imperative for achieving sustainable development in the region. Over the past decade, several Arab countries have actively engaged in seminars and research focused on recycling and green technology. Notably, countries like Saudi Arabia and the United Arab Emirates have implemented regulations and laws to promote green buildings and make them a prerequisite for foreign investment. The Saudi Arabian Ministry of Housing has introduced the "Mostadam" system, which rates buildings based on their environmental sustainability. This classification system encompasses a range of technical requirements that projects must adhere to in order to obtain certification, recognizing their commitment and excellence in sustainable practices.

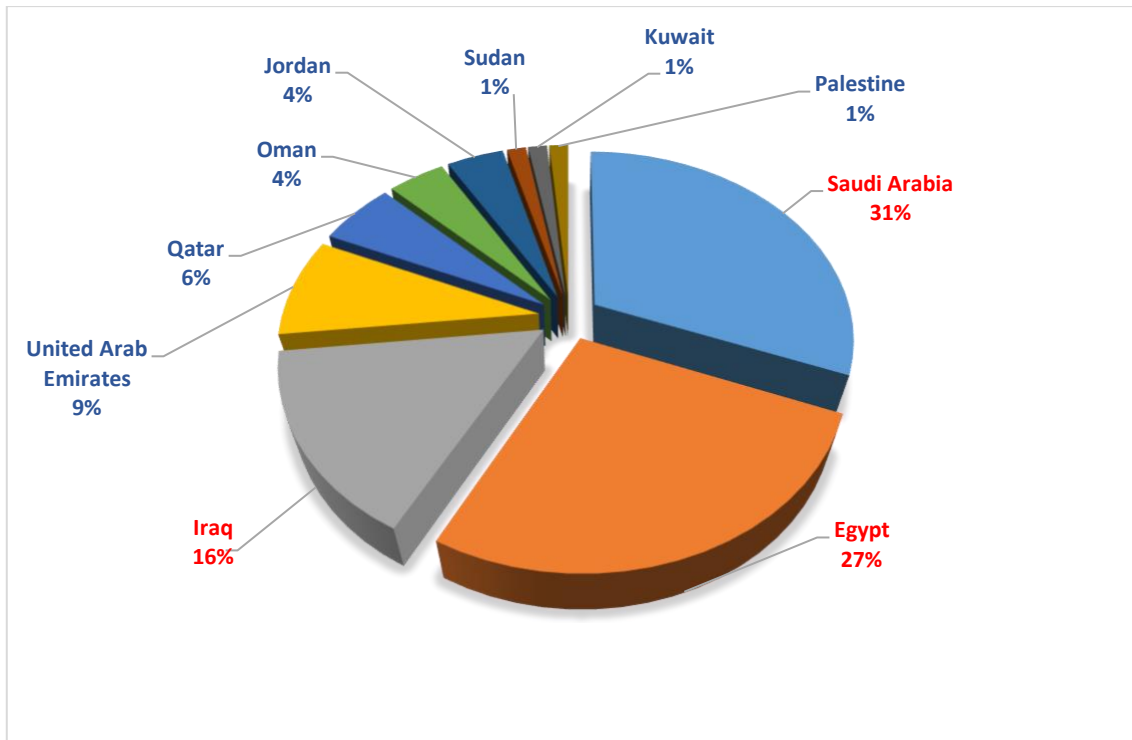


Figure 4.8 Top ten publishing Arab countries

Political turmoil, crises, and wars have significantly hindered technological advancements and scientific research in Arab countries such as Iraq. As a result, traditional waste disposal methods became more cost-effective than recycling. However, there has been a recent shift towards sustainable development, green building, and recycling in the policies of most Arab nations. This change was spurred by their participation in the Sustainable Development Summit held at the United Nations Headquarters in New York from September 25 to 27, 2015. During the summit, a plan called "Transforming our world: the 2030 Agenda for Sustainable Development" was established, with the attendance of 77 countries, including China.

The conference outlined 17 goals and 169 objectives for sustainable development, one of which emphasized the facilitation of sustainable and resilient infrastructure development. It also stressed the importance of promoting scientific research, enhancing technological capabilities in industrial sectors, fostering innovation, increasing the number of workers dedicated to research and development per one million people, and boosting public and private sector investments in sustainable development research and development.

Figure 4.6 illustrates the contributions of Arab countries to research publications in the field, as documented in the Scopus database. The Kingdom of Saudi Arabia ranks first in this regard, followed by Egypt and then Iraq.

4.6 Contributing Authors

The average citation count was calculated by dividing the total number of citations by each author's total number of publications. According to Figure 4.7, Poon C.S. had the highest number of publications (7). However, when it comes to citations, Raut, S.P. received the most citations (300). Evaluating a researcher's effectiveness independently can be challenging. Alternatively, The author's evaluation can be established by contrasting various variables individually or cooperatively. In terms of citation count, Raut, S.P. holds the top position with 300 citations, followed by Poon C.S. with 274 citations, and [6] in third place with 194 citations.

Figure 4.9 illustrates the level of collaboration and references between authors, with each group categorized by country using specific colors. Among the countries represented, China has the highest number of authors in the field of study.

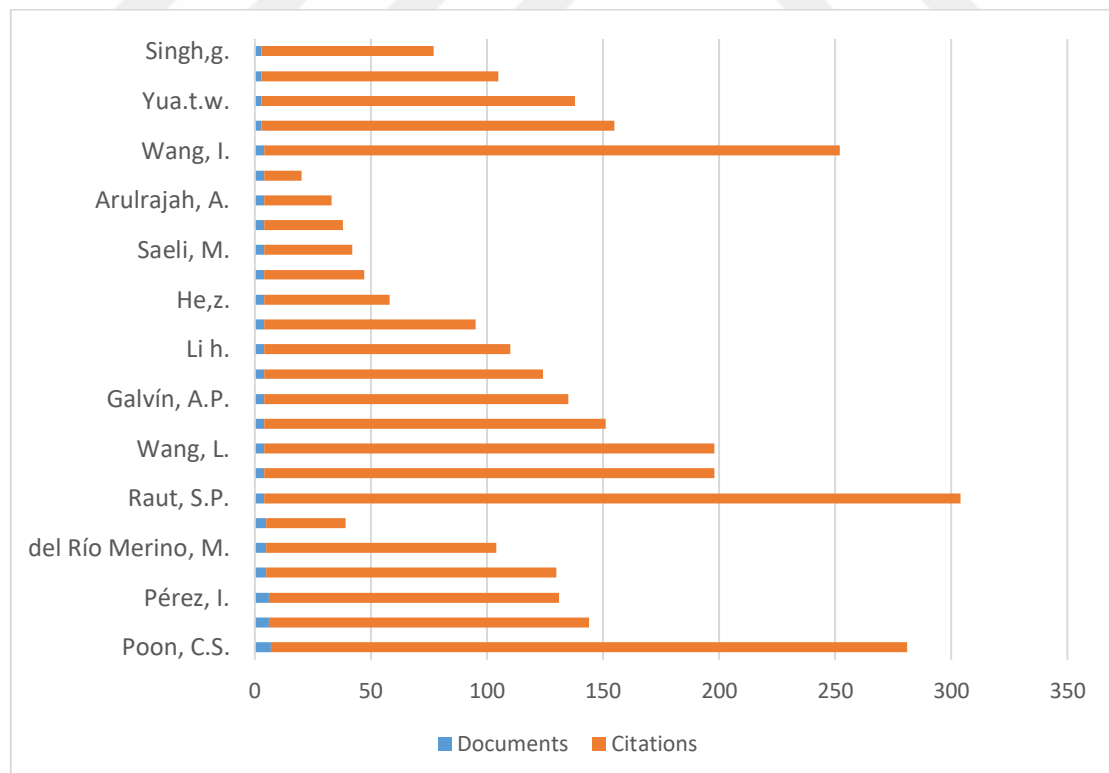


Figure 4.9 Top contributing authors in the relevant

4.7 The Most Important Sources for Construction Waste Management Studies

Table 3.7 shows the most published sources of articles in the field and scope of the research, in addition to the citation percentage and the strength of the association. The first three sources to provide data on the issue of sustainability and recycling as show in are Figure 4.10 are: Construction and building materials, Journal of cleaner production and Sustainability (Switzerland).

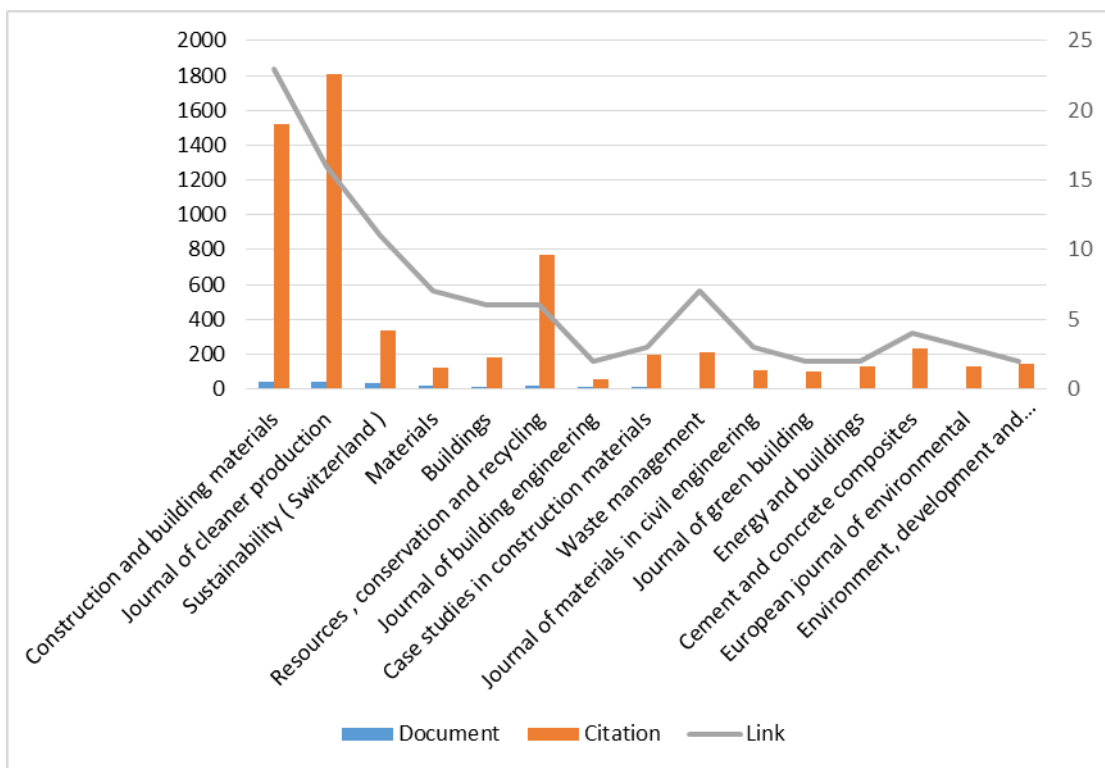


Figure 4.10 The most productive sources for articles

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

In order to encourage sustainable building practices, the purpose of this study was to conduct a scientometric analysis of the use of recycled materials in concrete. The study's main objectives were to identify the pertinent research areas, examine the publication patterns of articles, identify the most significant sources, look at the co-occurrence of keywords, find the most widely read articles and authors, and identify the countries that have invested in the use of recycled waste construction materials in concrete. To accomplish this, bibliometric data from the Scopus database spanning the last two decades (2010-2023) was collected and analyzed using VOS viewer. Based on the analysis, the following conclusions were drawn:

- 1- Researchers' interest in recycling materials in construction and sustainable development has increased significantly in recent years. The percentage of research for the years 2020 to 2023 exceeded approximately 60% of the total research published during the past decade. This indicates that the use of recycled materials , geopolymers concrete and alternatives to cement is more common than before.
- 2- The most active research fields include geopolymers concrete (secondary cementitious materials) SCMs (and recycled aggregate concrete(RAC) ,
- 3- China, the United States and India had the highest number of publications, with 74, 55 and 53 documents respectively, focusing on the use of recycled materials in sustainable construction, according to an analysis of countries that contributed to the literature. As a result, these countries demonstrated the significant impact of the use of agricultural and industrial waste, as well as construction waste, in improving the properties of concrete, in addition to the environmental impact it leaves if these wastes are left in landfill sites.
- 4- The political and economic obstacles that most Arab countries have suffered have affected scientific research and sustainable construction technology. The crises and wars that Iraq went through over two decades led to a clear decline

in the path of technology and scientific research in various fields. Including recycling and sustainable development, as a result of the migration of many researchers, the lack of funding for scientific research and the adoption of the principle of ease by using traditional methods of waste disposal. At the lowest cost. However, after 2018, the interest and orientation of Arab countries towards recycling and waste management technology emerged. through making contributions to the publication of research and carrying out relevant academic studies.

- 5- Several studies and papers have been published in the fields of material recycling, sustainable development, and green buildings, highlighting the collaboration and interdependence among authors. VOS viewer maps were utilized to assess knowledge sharing and citation patterns. Among the highly referenced papers, those authored by Raut, S.P. stood out. In particular, Raut, S.P.'s 2011 paper titled "Development of Sustainable Construction Material Using Industrial and Agricultural Solid Waste: A Review of Waste-create Bricks" garnered the highest number of citations in the past decade.
- 6- The exploration of alternatives to cement concrete has garnered significant attention from researchers, particularly in the fields of architecture and design. Bioreceptive concrete (used in green buildings), Cemfree, and Taktil are among the notable alternatives. They eliminate the need for cement in concrete by replacing it with supplementary cementitious materials such as artificial pozzolans.
- 7- In addition to the fact that green concrete composed of industrial or agricultural waste, which is considered secondary cement materials (SCMs), is environmentally friendly concrete, it is able to improve the properties of concrete and its durability to a certain extent. Otherwise, it was observed that an increase in the percentage of SCMs led to a weakness in the properties of concrete, and therefore a study must be conducted. About the greater use of SCMs without deterioration in material properties.
- 8- Most researchers in the field of recycling aggregate have indicated a decrease in some of the mechanical properties of recycled aggregate concrete. These include cross cracks and fractures that formed during the recycling process, weak links between the old mortar and aggregate, and the existence of weak and permeable mortar adhering to the recycled aggregate.

5.2 RECOMMENDATIONS

- 1- According to the principle that we not only inherited the earth from previous generations but also borrowed it from our grandchildren, sustainability is the key to the future in order to preserve the earth that embraces us all. The links between the articles in the network and the visual maps in VOSviewer are evidence that most articles cite previous research. Therefore, scientists and researchers must focus on sustainability and develop creative methods for waste management, exploring inventive recycling techniques, and promoting the development of alternative and renewable energy sources.
- 2- There are some issues in this research that are important for future research, including:
 - Geopolymer concrete, which consists of metakaolin, fly ash, and recycled fibers reinforced with a proportion of reinforcing bars, has a bearing capacity and compressive capacity (under static and dynamic loads) much greater than cement concrete. Therefore, it is significant for future studies to focus on this type of concrete for its flexibility and ability to resist and absorb shocks, which makes it appropriate for use in earthquake-resistant structures.
 - Research results showed a clear decrease in the properties of concrete in terms of compressive, tensile strength and modulus of elasticity by certain percentages when replacing natural aggregate with recycled aggregate. This requires more research to investigate the enhancement of mechanical properties of recycled aggregates.

REFERENCES

- [1] S. Balderstone, "Sustainability Forum Discussion Paper Built Heritage: A Major Contributor to Environmental, Social and...", Research Gate, [Online]. https://www.researchgate.net/publication/335542117_SUSTAINABILITY_FORUM_DISCUSSION_PAPER_Built_Heritage_A_Major_Contributor_to_Environmental_Social_and_Economic_Sustainability, 10.3.2004.
- [2] S. Marcelino-Sádaba, L. F. González-Jaen, and A. Perez-Ezcurdia, "Using project management as a way to sustainability. From a comprehensive review to a framework definition," *Journal of Cleaner Production*, vol. 99, pp. 1–16, 2015.
- [3] P. B. Lowry, D. Romans, and A. Curtis, "Global Journal Prestige and Supporting Disciplines: A Scientometric Study of Information Systems Journals," *Journal of the Association for Information Systems*, vol. 5, no. 2, pp. 29–77, 2004.
- [4] P. Glavič and R. K. Lukman, "Review of sustainability terms and their definitions," *Journal of Cleaner Production*, vol. 15, no. 18, pp. 1875–1885, 2007.
- [5] O. Faniran and G. Caban, "Minimizing waste on construction project sites," *Engineering, Construction and Architectural Management*, vol. 5, no. 2, pp. 182–188, 1998.
- [6] H. Baumann, F. Boons, and A. Bragd, "Mapping the green product development field: engineering, policy and business perspectives," *Journal of Cleaner Production*, vol. 10, no. 5, pp. 409–425, 2002.
- [7] P. B. Lowry, S. L. Humpherys, J. Malwitz, and J. Nix, "A Scientometric Study of the Perceived Quality of Business and Technical Communication Journals," *IEEE Transactions on Professional Communication*, vol. 50, no. 4, pp. 352–378, 2007.
- [8] R. Valdes-Vasquez and L. Klotz, "Social Sustainability Considerations during Planning and Design: Framework of Processes for Construction Projects," *Journal of the Construction Division and Management*, vol. 139, no. 1, pp. 80–89, 2013.
- [9] K. Doust, G. Battista, and P. G. Rundle, "Front-end construction waste minimization strategies," *Australian Journal of Civil Engineering*, vol. 19, no. 1, pp. 1–11, 2021.
- [10] A. A. Chadegani et al., "A Comparison between Two Main Academic Literature Collections: Web of Science and Scopus Databases," *Asian Social Science*, vol. 9, no. 5, Apr. 2013.
- [11] T. Whelan, "The Comprehensive Business Case for Sustainability," *Harvard Business Review*, <https://hbr.org/2016/10/the-comprehensive-business-case-for-sustainability>, 06.01.2017.
- [12] N. Agarwal and U. Rathod, "Defining 'success' for software projects: An exploratory revelation," *International Journal of Project Management*, vol. 24, no. 4, pp. 358–370, 2006.
- [13] E. AL Mahmoud and H. Doloi, "Assessment of social sustainability in construction projects using social network analysis," *Facilities*, vol. 33, no. 3/4, pp. 152–176, 2015.

[ustainable_building_html_Insights_from_Building_Professionals_on_Government_Initiatives_to_Promote_Environmentally_Sound_Practices](#), 31.10. 2017.

- [27] G. A. Blengini, M. Busto, M. Fantoni, and D. Fino, “Eco-efficient waste glass recycling: Integrated waste management and green product development through LCA,” *Waste Management*, vol. 32, no. 5, pp. 1000–1008, 2012.
- [28] M. J. Milne and R. Gray, “W(h)ither Ecology? The Triple Bottom Line, the Global Reporting Initiative, and Corporate Sustainability Reporting,” *Journal of Business Ethics*, vol. 118, no. 1, pp. 13–29, 2013.
- [29] G. Ofori, “Sustainable construction: principles and a framework for attainment - comment,” *Construction Management and Economics*, vol. 16, no. 2, pp. 141–145, 1998.
- [30] E. Ojo, “Barriers in implementing green supply chain management in construction industry,” <https://www.semanticscholar.org/paper/Barriers-in-implementing-green-supply-chain-in-Ojo-Mbowa>, 2014.
- [31] G. Author, “6 Benefits of Becoming a Sustainable Business,” *Environment Energy Leader*,” 2023.
- [32] L. Sabini, D. Muzio, and N. Alderman, “25 years of ‘sustainable projects’. What we know and what the literature says,” *International Journal of Project Management*, vol. 37, no. 6, pp. 820–838, 2019.
- [33] S. Goulden, E. Erell, Y. Garb, and D. Pearlmutter, “Green building standards as socio-technical actors in municipal environmental policy,” *Building Research & Information*, vol. 45, no. 4, pp. 414–425, 2017.
- [34] L. Shen, V. W. Y. Tam, L. Tam, and Y. Ji, “Project feasibility study: the key to successful implementation of sustainable and socially responsible construction management practice,” *Journal of Cleaner Production*, vol. 18, no. 3, pp. 254–259, Feb. 2010.
- [35] J. R. Jiménez, J. Ayuso, F. Agrela, M. López, and A. P. Galvín, “Utilisation of unbound recycled aggregates from selected CDW in unpaved rural roads,” *Resources Conservation and Recycling*, vol. 58, pp. 88–97, 2012.
- [36] S. M. Khoshnava, R. Rostami, A. Valipour, M. Ismail, and A. R. Rahmat, “Rank of green building material criteria based on the three pillars of sustainability using the hybrid multi criteria decision making method,” *Journal of Cleaner Production*, vol. 173, pp. 82–99, Feb, 2018.
- [37] Elsevier, “International Encyclopedia of the Social & Behavioral Sciences - 2nd Edition,” <https://www.elsevier.com/books/international-encyclopedia-of-the-social-and-behavioral-sciences/wright/978-0-08-097086-8>. 17. 2, 2015.
- [38] P. B. Lowry, D. Romans, and A. Curtis, “Global Journal Prestige and Supporting Disciplines: A Scientometric Study of Information Systems Journals,” *Journal of the Association for Information Systems*, vol. 5, no. 2, pp. 29–77, 2004.
- [39] G. G. Karuga, P. B. Lowry, and V. J. Richardson, “Assessing the Impact of Premier Information Systems Research over Time,” *Communications of the Association for Information Systems*, 2007.
- [40] F. Colangelo, A. Forcina, I. Farina, and A. Petrillo, “Life Cycle Assessment (LCA) of Different Kinds of Concrete Containing Waste for Sustainable

- Construction,” *Buildings*, vol. 8, no. 5, p. 70, 2018.
- [41] H. Quiasrawi, “Closed-loop recycling of recycled concrete aggregates,” *Journal of Cleaner Production*, vol. 37, pp. 243–248, 2012.
- [42] D. Bertsimas, E. Brynjolfsson, S. Reichman, and J. Silberholz, “OR Forum—Tenure Analytics: Models for Predicting Research Impact,” *Operations Research*, vol. 63, no. 6, pp. 1246–1261, 2015.
- [43] B. Sohrabi and H. Iraj, “The effect of keyword repetition in abstract and keyword frequency per journal in predicting citation counts,” *Scientometrics*, vol. 110, no. 1, pp. 243–251, 2017.
- [44] P. B. Lowry, “Assessing Leading Institutions, Faculty, and Articles in Premier Information Systems Research Journals.” https://papers.ssrn.com/sol3/papers.cfm?abstract_id=1021603, 2019.
- [45] S. H. Ghaffar, M. Burman, and N. Braimah, “Pathways to circular construction: An integrated management of construction and demolition waste for resource recovery,” *Journal of Cleaner Production*, vol. 244, p. 118710, 2020.
- [46] G. Habert, J.-B. D. De Lacaillerie, and N. Roussel, “An environmental evaluation of geopolymer based concrete production: reviewing current research trends,” *Journal of Cleaner Production*, vol. 19, no. 11, pp. 1229–1238, 2011.
- [47] S. Huang et al., “Plastic Waste Management Strategies and Their Environmental Aspects: A Scientometric Analysis and Comprehensive Review,” *International Journal of Environmental Research and Public Health*, vol. 19, no. 8, p. 4556, 2022.
- [48] D. J. Coughlin, M. Campbell, and B. J. Jansen, “A web analytics approach for appraising electronic resources in academic libraries,” *Journal of the Association for Information Science and Technology*, vol. 67, no. 3, pp. 518–534, 2016.
- [49] D. J. De Solla Price, “Networks of Scientific Papers,” *Science*, vol. 149, no. 3683, pp. 510–515, 1965.
- [50] Z. Tang, W. Li, Y. Hu, J. L. Zhou, and V. W. Y. Tam, “Review on designs and properties of multifunctional alkali-activated materials (AAMs),” *Construction and Building Materials*, vol. 200, pp. 474–489, 2019.
- [51] Z. Sun et al., “Synthesis and thermal behavior of geopolymer-type material from waste ceramic,” *Construction and Building Materials*, vol. 49, pp. 281–287, 2013.
- [52] L. Sun, M. Fujii, T. Tasaki, H. Dong, and S. Ohnishi, “Improving waste to energy rate by promoting an integrated municipal solid-waste management system,” *Resources Conservation and Recycling*, vol. 136, pp. 289–296, 2018.
- [53] Y. Chen et al., “Life cycle assessment of end-of-life treatments of waste plastics in China,” *Resources Conservation and Recycling*, vol. 146, pp. 348–357, 2019.
- [54] A. Laurent et al., “Review of LCA studies of solid waste management systems – Part I: Lessons learned and perspectives,” *Waste Management*, vol. 34, no. 3, pp. 573–588, Mar. 2014.
- [55] S. of C. and E. Engineering, “Lightweight aerated metakaolin-based geopolymer incorporating municipal solid waste incineration bottom ash as gas-forming agent,” NTU Singapore, <https://dr.ntu.edu.sg/handle/10356/139888>, 2018.

- [56] W.-P. Zhu, X. Chen, L. J. Struble, and E.-H. Yang, “Quantitative characterization of aluminosilicate gels in alkali-activated incineration bottom ash through sequential chemical extractions and deconvoluted nuclear magnetic resonance spectra,” *Cement & Concrete Composites*, vol. 99, pp. 175–180, 2019.
- [57] W.-P. Zhu, P. J. Teoh, Y. Liu, Z. Chen, and E.-H. Yang, “Strategic utilization of municipal solid waste incineration bottom ash for the synthesis of lightweight aerated alkali-activated materials,” *Journal of Cleaner Production*, vol. 235, pp. 603–612, 2019.
- [58] J. Xu, Z. Chen, Z. M. Yaseen, X. Zhao, and C. Demartino, “A critical assessment of the compressive behavior of reinforced recycled aggregate concrete columns,” *Engineering Structures*, vol. 161, pp. 161–175, 2018.
- [59] D. Hou and A. Al-Tabbaa, “Sustainability: A new imperative in contaminated land remediation,” *Environmental Science & Policy*, vol. 39, pp. 25–34, 2014.
- [60] L. Reig, M. A. Sanz, M. V. Borrachero, J. Monzó, L. Soriano, and J. Payá, “Compressive strength and microstructure of alkali-activated mortars with high ceramic waste content,” *Ceramics International*, vol. 43, no. 16, pp. 13622–13634, 2017.
- [61] H. A. Abdel-Gawwad, E. Heikal, H. El-Didamony, F. S. Hashim, and A. A. M. Mohammed, “Recycling of concrete waste to produce ready-mix alkali activated cement,” *Ceramics International*, vol. 44, no. 6, pp. 7300–7304, 2018.
- [62] J. Fořt et al., “Application of waste brick powder in alkali activated aluminosilicates: Functional and environmental aspects,” *Journal of Cleaner Production*, vol. 194, pp. 714–725, 2018.
- [63] G. F. Huseien et al., “Waste ceramic powder incorporated alkali activated mortars exposed to elevated Temperatures: Performance evaluation,” *Construction and Building Materials*, vol. 187, pp. 307–317, 2018.
- [64] S. Abdul, “Properties of ceramic tile waste based alkali-activated mortars incorporating GBFS and fly ash,” *www.academia.edu*, Jan. 2019, https://www.academia.edu/94196990/Properties_of_ceramic_tile_waste_based_alkali_activated_mortars_incorporating_GBFS_and_fly_ash, 05.01.2019.
- [65] G. F. Hussein, A. R. M. Sam, K. W. Shah, J. Mirza, and M. Md. Tahir, “Evaluation of alkali-activated mortars containing high volume waste ceramic powder and fly ash replacing GBFS,” *Construction and Building Materials*, vol. 210, pp. 78–92, 2019.
- [66] G. F. Huseien, A. R. M. Sam, and J. Mirza, “Effects of ceramic tile powder waste on properties of self-compacted alkali-activated concrete,” *Construction and Building Materials*, vol. 236, p. 117574, 2020.
- [67] M. Gandoman and M. Kokabi, “Sound barrier properties of sustainable waste rubber/geopolymer concretes,” *Iranian Polymer Journal*, vol. 24, no. 2, pp. 105–112, 2015.
- [68] P. Bhada-Tata and D. Hoornweg, “What a Waste : A Global Review of Solid Waste Management,” *World Bank*, pp. 1–116, <https://openknowledge.worldbank.org/bitstream/10986/17388/8/68135>, 30.03.2012

- [69] L. Zhang, T. Ngo, and A. Kashani, "Glass waste versus sand as aggregates: The characteristics of the evolving geopolymer binders," *Journal of Cleaner Production*, vol. 193, pp. 593–603, 2018.
- [70] N. Saikia and J. De Brito, "Use of plastic waste as aggregate in cement mortar and concrete preparation: A review," *Construction and Building Materials*, vol. 34, pp. 385–401, 2012.
- [71] V. W. Y. Tam and W. Lu, "Construction Waste Management Profiles, Practices, and Performance: A Cross-Jurisdictional Analysis in Four Countries," *Sustainability*, vol. 8, no. 2, p. 190, 2016.
- [72] I. Y. Wuni, G. Q. Shen, and R. Osei-Kyei, "Scientometric review of global research trends on green buildings in construction journals from 1992 to 2018," *Energy and Buildings*, vol. 190, pp. 69–85, 2019.
- [73] J. Solís-Guzmán, C. Rivero-Camacho, D. Alba-Rodríguez, and A. Martínez-Rocamora, "Carbon Footprint Estimation Tool for Residential Buildings for Non-Specialized Users: OERCO2 Project," *Sustainability*, vol. 10, no. 5, p. 1359, 2018.
- [74] B. Huang, X. Wang, H. W. Kua, Y. Geng, R. Bleischwitz, and J. Ren, "Construction and demolition waste management in China through the 3R principle," *Resources Conservation and Recycling*, vol. 129, pp. 36–44, 2017.
- [75] Md. U. Hossain, L. Wang, I. K. M. Yu, K.-H. Kim, and C. S. Poon, "Environmental and technical feasibility study of upcycling wood waste into cement-bonded particleboard," *Construction and Building Materials*, vol. 173, pp. 474–480, 2018.
- [76] M. Yeheyis, K. Hewage, M. S. Alam, C. Eskicioglu, and R. Sadiq, "An overview of construction and demolition waste management in Canada: a lifecycle analysis approach to sustainability," *Clean Technologies and Environmental Policy*, vol. 15, no. 1, pp. 81–91, 2013.
- [77] J.-L. Galvez-Martos, D. Styles, H. Schoenberger, and B. Zeschmar-Lahl, "Construction and demolition waste best management practice in Europe," *Resources Conservation and Recycling*, vol. 136, pp. 166–178, 2018.
- [78] H. Yuan, "A SWOT analysis of successful construction waste management," *Journal of Cleaner Production*, vol. 39, pp. 1–8, 2013.
- [79] P. Xu, Q. Zhao, W. Qiu, Y. Xue, and N. Li, "Microstructure and Strength of Alkali-Activated Bricks Containing Municipal Solid Waste Incineration (MSWI) Fly Ash Developed as Construction Materials," *Sustainability*, vol. 11, no. 5, p. 1283, 2019.
- [80] T. Ngo, A. Kashani, G. Imbalzano, K. Nguyen, and D. S. C. Hui, "Additive manufacturing (3D printing): A review of materials, methods, applications and challenges," *Composites Part B-engineering*, vol. 143, pp. 172–196, 2018.
- [81] B. Lothenbach, K. Scrivener, and R. D. Hooton, "Supplementary cementitious materials," *Cement and Concrete Research*, vol. 41, no. 12, pp. 1244–1256, 2011.
- [82] E. Gartner, "Industrially interesting approaches to 'low-CO2' cements," *Cement and Concrete Research*, vol. 34, no. 9, pp. 1489–1498, 2004.

- [83] B. B. Sabir, S. Wild, and J. Bai, "Metakaolin and calcined clays as pozzolans for concrete: a review," *Cement & Concrete Composites*, vol. 23, no. 6, pp. 441–454, 2001.
- [84] D. Khale and R. Chaudhary, "Mechanism of geopolymerization and factors influencing its development: a review," *Journal of Materials Science*, vol. 42, no. 3, pp. 729–746, 2007.
- [85] I. Z. Bribián, A. V. Capilla, and A. A. Usón, "Life cycle assessment of building materials: Comparative analysis of energy and environmental impacts and evaluation of the eco-efficiency improvement potential," *Building and Environment*, vol. 46, no. 5, pp. 1133–1140, 2011.
- [86] J. S. Damtoft, J. Lukasik, D. Herfort, D. Sorrentino, and E. Gartner, "Sustainable development and climate change initiatives," *Cement and Concrete Research*, vol. 38, no. 2, pp. 115–127, 2008.
- [87] P. Xu, Q. Zhao, W. Qiu, Y. Xue, and N. Li, "Microstructure and Strength of Alkali-Activated Bricks Containing Municipal Solid Waste Incineration (MSWI) Fly Ash Developed as Construction Materials," *Sustainability*, vol. 11, no. 5, p. 1283, 2019.
- [88] S. P. Raut, R. V. Ralegaonkar, and S. A. Mandavgane, "Development of sustainable construction material using industrial and agricultural solid waste: A review of waste-create bricks," *Construction and Building Materials*, vol. 25, 2011.
- [89] S. Manzi, C. Mazzotti, and M. C. Bignozzi, "Short and long-term behavior of structural concrete with recycled concrete aggregate," *Cement & Concrete Composites*, vol. 37, pp. 312–318, 2013.
- [90] D. Hou and A. Al-Tabbaa, "Sustainability: A new imperative in contaminated land remediation," *Environmental Science & Policy*, vol. 39, pp. 25–34, 2014.
- [91] S. H. Ghaffar, M. Burman, and N. Braimah, "Pathways to circular construction: An integrated management of construction and demolition waste for resource recovery," *Journal of Cleaner Production*, vol. 244, p. 118710, 2020.
- [92] J. Xie, Y.-C. Guo, L. Liu, and Z. Xie, "Compressive and flexural behaviours of a new steel-fibre-reinforced recycled aggregate concrete with crumb rubber," *Construction and Building Materials*, vol. 79, pp. 263–272, 2015.
- [93] Z. Li, G. Q. Shen, and M. Alshawi, "Measuring the impact of prefabrication on construction waste reduction: An empirical study in China," *Resources Conservation and Recycling*, vol. 91, pp. 27–39, 2014.
- [94] I. Marie and H. Quisrawi, "Closed-loop recycling of recycled concrete aggregates," *Journal of Cleaner Production*, vol. 37, pp. 243–248, 2012.
- [95] S. M. Khoshnava, R. Rostami, A. Valipour, M. Ismail, and A. R. Rahmat, "Rank of green building material criteria based on the three pillars of sustainability using the hybrid multi criteria decision making method," *Journal of Cleaner Production*, vol. 173, pp. 82–99, 2018.
- [96] J. R. Jiménez, J. Ayuso, F. Agrela, M. López, and A. P. Galvín, "Utilisation of unbound recycled aggregates from selected CDW in unpaved rural roads," *Resources Conservation and Recycling*, vol. 58, pp. 88–97, 2012.

- [97] R. Herrador, P. Perez, L. Garach, and J. Ordóñez, "Use of Recycled Construction and Demolition Waste Aggregate for Road Course Surfacing," *Journal of Transportation Engineering*, vol. 138, no. 2, pp. 182–190, 2012.
- [98] Z. Tang, W. Li, V. W. Y. Tam, and C. Xue, "Advanced progress in recycling municipal and construction solid wastes for manufacturing sustainable construction materials," *Resources Conservation & Recycling X*, vol. 6, p. 100036, 2020.
- [99] E. F. Ledesma, J. A. Jiménez, J. Ayuso, J. M. G. Fernández, and J. De Brito, "Maximum feasible use of recycled sand from construction and demolition waste for eco-mortar production – Part-I: ceramic masonry waste," *Journal of Cleaner Production*, vol. 87, pp. 692–706, 2015.
- [100] F. Colangelo, A. Forcina, I. Farina, and A. Petrillo, "Life Cycle Assessment (LCA) of Different Kinds of Concrete Containing Waste for Sustainable Construction," *Buildings*, vol. 8, no. 5, p. 70, 2018.
- [101] G. A. Blengini, M. Busto, M. Fantoni, and D. Fino, "Eco-efficient waste glass recycling: Integrated waste management and green product development through LCA," *Waste Management*, vol. 32, no. 5, pp. 1000–1008, 2012.
- [102] L. Zhang, A. O. Sojobi, V. Kodur, and K. M. Liew, "Effective utilization and recycling of mixed recycled aggregates for a greener environment," *Journal of Cleaner Production*, vol. 236, p. 117600, 2019

PUBLICATIONS FROM THE THESIS

Conference Papers

1. Ghadah Hashoosh, and Asli Pelin Gürkün," Scientometric analysis of material recycling in sustainable construction," ORAL SUMMARY PRESENTATION, presented at the 3rd International Conference on Access to Recent Advances in Engineering and Digitalization, March 15–17, 2023. Istanbul, Turkey.

