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Sustainable Asphalt Mixtures : a Scientific Metric Analysis and Bibliometrics Review

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Abstract

The environmental effects of building a new road are numerous and include significant material and energy use. Additionally, there has been a notable increase in the price of crude oil, the primary source of bituminous binder, in recent years (most notably in 2001–2008). The cost of asphalt mixtures as a whole has gone up as a result. Measures with strong sustainability credentials must be extensively implemented in order to fight price increases and encourage sustainable activities. The asphalt pavement business may become more sustainable and cost-efficient by creating new materials and technologies that include trash, recycled resources, and greener components into the asphalt mixture production cycle**.**

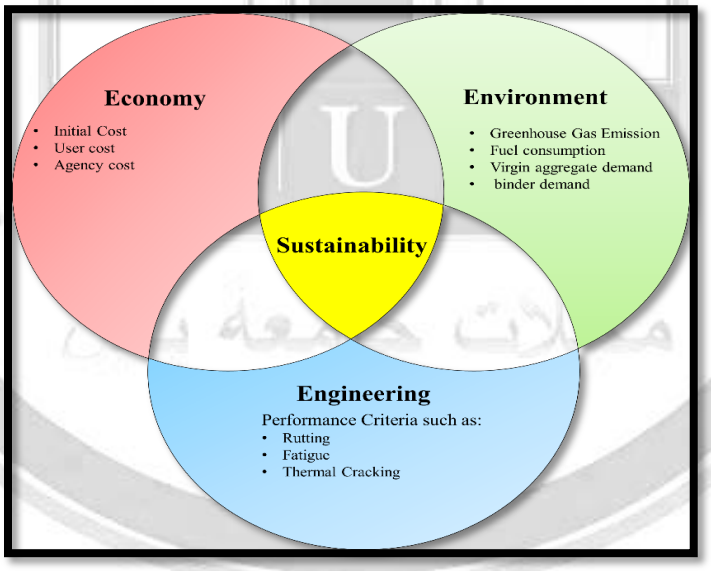
Sustainable asphalt mixtures demonstrate improved durability and longer service life, reducing the need for frequent maintenance and rehabilitation. This leads to cost savings and reduced disruption to traffic. The purpose of this study is to determine which nations and institutions have published the greatest number of articles on the topic of sustainable asphalt mixtures, as well as to identify and aggregate the most noteworthy research papers using "Dimensions" and analyze the data using the VOS viewer software. Additionally, it was done to find out more about the writers' collaboration

Keywords : Sustainable asphalt mixtures, Environment, Eco-friendly material ,Recycling road.

Introduction

In the present era, the prioritization of environmental preservation and endurance has emerged as fundamental declarations in all projects. Specifically, addressing the challenge of how and where to effectively dispose of the substantial quantity of daily waste has become a paramount global concern, especially in light of the escalating waste production. To address this environmental challenge, various recycling methodologies and extensive research endeavors focusing on integrating plastic waste into bitumen and asphalt mixtures have been advanced [1]. Sustainability entails the satisfaction of human necessities and the progression of technology while minimizing the impact on the environment and economy. The transportation sector is crucial for meeting the needs of individuals, and there is a significant emphasis on establishing sustainable transportation infrastructure. With approximately 83.5% of the entire road surface, asphalt stands as the predominant component of the road network assets in the United States [2] . Authors, such as Spray, have conducted research on sustainability and life cycle cost (LCC) of pavements, specifically focusing on life cycle assessment (LCA) in relation to environmental issues. LCA is generally defined as the consideration of environmental aspects and

potential environmental impacts, including the use of resources and the environmental consequences of releases, throughout a product's life cycle, from raw material acquisition through production, use, end-of-life treatment, recycling, and final disposal. Additionally, carbon footprint, as a subset of LCA, is commonly utilized to estimate the global warming potential of greenhouse gas (GHG) emissions in product life cycles [3].Researchers have endeavored to find solutions to reduce air pollution and limit the exploitation of natural resources for asphalt from an environmental standpoint. In a recent development, the Mauna Loa Observatory has documented an unprecedented CO2 measurement of over 410 parts per million (ppm) [4].In the year 2007, an estimated (1.6) billion metrics tons for asphalt was manufactured on a global scale [5]. The outcome of this process was the production of (14.4 × 106 m3) of fuel , (1.28 × 104 GWh) of electrical consumptions, and (46.08) million tons of (CO2) emissions .These emissions account a mere (0.15%) for the global (CO2) emissions. The constructions of pavement , conversely, encompasses three distinct stages, namely transportation, paving, and compaction of asphalt mixtures. It is worth noting that only the final stage has the potential to mitigate emissions if modifications are implemented to enhance compatibility. Additionally, the energy consumption and emissions associated with the service, maintenance, and end-of-life phases can be curtailed through the enhanced performance of asphalt mixtures. Another crucial environmental consideration in the production of asphalt mixtures is waste management. The use of recycled aggregate, as well as the modification of asphalt through waste polymers and by-products, serve as effective measures to safeguard natural resources and prevent the disposal of



Figure(1) Engineering Sustainability of Pavements.

Environmentally harmful and hazardous waste materials [6]. The role of the economy in the industry is of utmost importance, and any effort to enhance the environment must adhere to economic constraints. Given that the construction of roads requires a significant amount of energy and depletes natural resources, any environmental improvements would yield certain economic benefits. While it may be disheartening to experience an initial increase in costs as a result of environmental considerations, a thorough influencing the performance of asphalt mixtures play a significant role in

"life-cycle" analysis (LCA) , which ultimately determines the environmental and economically advantageousness l. Improved performance criterion ensures longer- lifespan and greater serviceability, thereby reducing the expenses associated with reconstruction, maintenance, and rehabilitation efforts. Furthermore, over the long term, fewer natural resources such as fuel, aggregate, and asphalt binder would be consumed. As such achieving the optimal equilibrium between engineering performance and environmental concerns, and economic considerations contributes for the sustainability of pavement assets **(Figure.1)** show studies on sustainability often focus on three key component economically developments- social developments,- and environmental protection [7].

Warm mix asphalt (WMA) technologies, along with the use of waste materials like recycled asphalt pavement (RAP) and recycled asphalt shingles (RAS), as well as crumb rubber modified (CRM), can reduce energy consumption and greenhouse gas emissions, extend the life cycle, and improve serviceability. Thus, the purpose of this study is to evaluate the engineering, economic, and environmental performance of the most widely used and authorized waste materials (RAP, RAS, and CRM) as well as the application of WMA technologies. Furthermore, the engineering properties of the less common waste materials, such as copper and steel slag, recovered plastic (RP), vacuum tower bottoms (VTB), and bio-binder modifiers, were the main focus of the examination.(Figure. 2) shows the structures of this study, which was adopt to investigate the escalation of " sustainability in the asphalt industrys" [2].

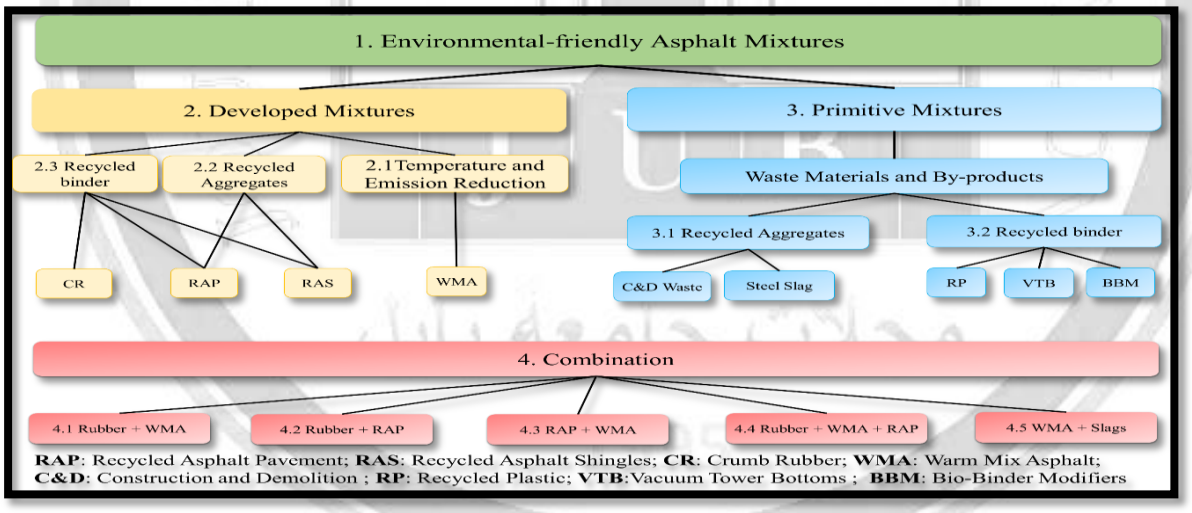
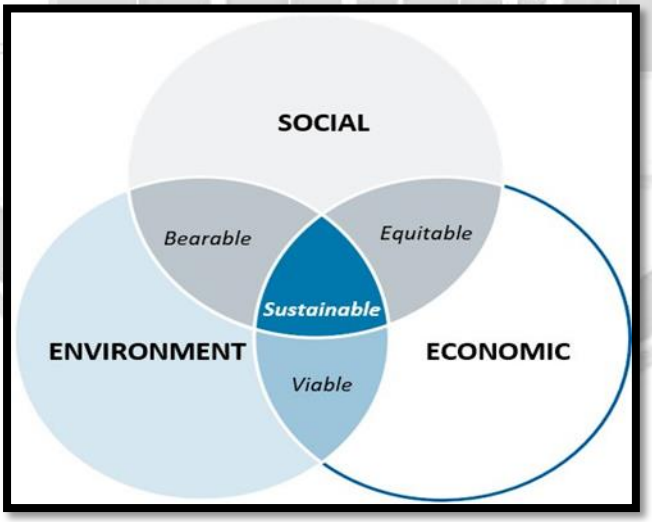


Figure (2) Flow Chart of the Research Content.

Materials and Methods:

Sustainable Materials

Sustainable development necessitates the utilization of a reduced quantity of raw natural material due to the exorbitant expense and energy consumptions associated with their extraction and transportation. Furthermore, sustainable developments, serves to diminish the release of (greenhouse gases) and employs recyclable material, all while preserving the standard requisites, The illustration depicted in (**Figure. 3)** shows cases the three interconnected realms that constitute sustainable development: economic development, social development, and environmental preservation. More specifically, the economically facet contribute to profitability and (cost-effectiveness) , while the social facet embodies the contribution of the standard of living and equal opportunities for the pursuit of "sustainability". Additionally, the environmentally facet delineates the utilization of natural resources - pollution prevention - and the preservation of biodiversity. It is evident from **(Figure. 3)** that WMA technology is inherently aligned with the principles of sustainable development, as it takes into account the environmentally, economically, and social aspect, thereby promoting equity and viability [7].Using waste materials in road constructions will reduce the overall environmental impact [8]**.** (WMA) technologies facilitate the incorporation of higher proportions of recycled material [7] , thereby enabling development for perpetual and sustainable pavements designs based on the principles (reclaim- recycle – reuse- and reduce). The utilization of waste material in the construction and rehabilitation of pavements has the potential to decrease energy consumptions. WMA pavements employ a range of recycled aggregates, such as (recycled asphalt pavement (RAP) - Recycled Asphalt Shingles (RAS) - construction and demolition waste,and industrial by-product) e.g." copper or steel slags" [2] .



Figure(3) Sustainable Development [7]

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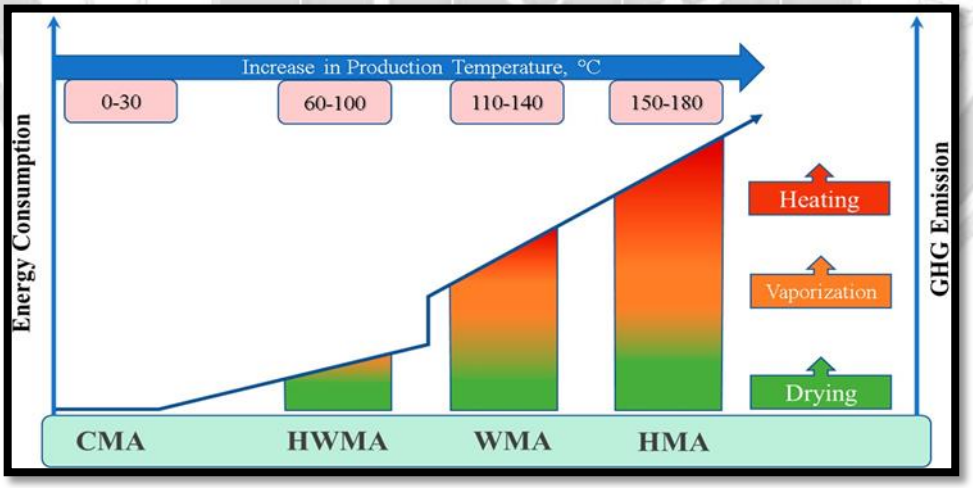
Component and Production of Hot Mix Asphalt and Warm- mix Asphalt of Asphalt Mixtures

WMA - HMA" share identical constituent, WMA presents ease of utilization, and its production necessitates no significant alterations to the preexisting HMA facility. Nevertheless, the fabrication of HMA engenders a greater proportion of CO2 emissions during the preliminary construction phase[9]. The sole disparity between WMA and HMA resides in their respective production temperatures [10]. While WMA is made at a temperature range of (110 to 140 ◦C), HMA preparation requires a high temperature range of 150 to 180 ◦C., **Table (1)** presents the advantages and disadvantages of HMA and WMA [11]. **(Figure.4)** shows the Classification of asphalt mixes based on production temperature [12].

Table (1) The Advantages and Disadvantages of Asphalt Mixes [11]

Mix Type	Production Temperature	Advantages	Disadvantages
Hot-mix asphalt	150–180 ˚C	• Superior mixture performance • Lower initial cost	• High production temperature • High emissions • High energy consumption
Warm-mix asphalt	110–140 ˚C	• Low production temperature • Low emissions • Energy saving • Better working conditions • Longer haul distance • Minor wear and tear on the plant • Less binder ageing	• Low mixture performance • Higher initial cost due to the use of additives • Poor aggregate coating and bonding



Figure(4) Classification of Asphalt Mixes Based on Production Temperature [12].

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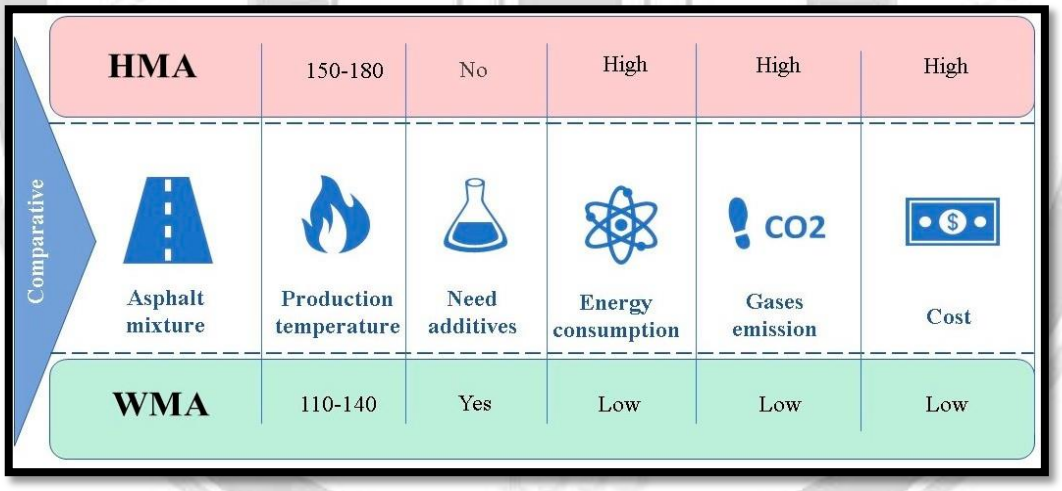
Temperature and Emission Reduction (Warm mix asphalt)

(WAM) mixtures , are asphalt mixtures that possess low temperatures for both mixing and compaction .These environmentally-conscious mixtures offer a more sustainable alternative to the conventional Hot mix asphalt (HMA) mixtures. In comparison, the conventional HMA mixtures necessitate a production temperature ranging from (150 to 190) degrees Celsius, whereas WMA mixtures can achieve a temperature reduction of (14 to 50) degrees Celsius depending on specific WMA technology employed [13] . The most significant advantages of WMA include the reduction in fuel consumption and GHG emissions, the enhancement of working conditions for paving crews by means of decreased harmful emissions, the mitigation of binder aging, the extension of hauling distance, the potential augmentation of field densities (thus improving compactability), and the elongation of paving seasons. Nevertheless, in comparison to conventional HMA, one can expect a substantial alteration in pavement performance because the declining in production temperatures and alterations to binder characteristics , For instance, while a decrease in binder oxidation may be heighten pavement cracking resistance, it may concurrently diminish moisture and rutting resistance [14]. **(Figure. 5).** The utilization of Warm Mix Asphalt (WMA) offers a multitude of advantages due to its diminished production temperature. Primarily, it presents a noteworthy reduction in environmental encumbrances, encompassing the mitigation of global warming. Moreover, it effectively curtails the discharge of noxious gases and pernicious fumes[11].



Figure(5) Comparison of HMA and WMA [11].

Environmental assessment

burning (fossil fuels and the application of heated binder) are the two primary origins of greenhouse gas emissions during the production stage . A decline in ” production” temperature yields a more environmentally friendly production process as it diminishes fuel utilization and lowers the temperature of the binder. Warm mix asphalt (WMA) yields asphalt mixtures that exhibit a reduction in fossil fuel consumption of about 20-40% when compared to conventional hot mix asphalt (HMA) [15]. WMA technologies have proven to be (highly effective in terms of reducing (GHG emissions) . These findings an derived from extensive stack emissions test conducted for a total of 15 projects across the globe . The results demonstrated a significant decrease in (carbon dioxide CO2), oxides of

nitrogen (NOx), and carbon monoxide (CO). However, it should be noted that in certain projects, there was an observed increase in sulfur dioxide (SO2). Additionally, a comprehensive investigation carried out as part of NCHRP report 779 examined the Three multi-technology projects in Michigan, Indiana, and New York State have stack emissions The results indicated that the application of warm mix asphalt led to noteworthy 20% reduction in (CO2) emissions compared to traditional hot mix asphalt, primarily due to a substantial 21% declining in fuel consumption [13] .

Overview of Recycled Asphalt Pavement Usage in Worldwide

The proportion of re- RAP used The recycled asphalt pavement (RAP) has gradually increased at numerous countries worldwide Currently, significant quantity of recycled material is utilized for the production of (HMA) and (WMA) mixes, exemplifying the optimal re-utilization of The recycled asphalt pavement aggregates as previously mentioned. Presently, based on multiple studies, incorporating a RAP content within the range of (15-20%) by weight is becoming, a standardized procedure for the creation of bituminous mixtures , The incorporation of (RAP)b in new compositions of asphalt concrete, accounting for up to 40% of the total mix weight, has been implemented in South Africa since 2009 A decade later, integrating in-plant recycling, with a RAP content of up to (40%) by weight, has become a customary industrial practice [16]. Recycling is considered a process with environmental and economic benefits as a sustainable strategy in the paving industry. Whereas , Reusing reclaimed asphalt pavement with fresh hot asphalt mixes (HMA) keeps it out of the landfill and helps cut down on the quantity of new materials (aggregate and asphalt binder) utilized.The aged asphalt binder and aggregate are still useful and can be utilized even though the old asphalt pavements have degraded and reached the end of their useful lives. For a long time, RAP materials have been combined with virgin materials to create new asphalt pavements that have proven to be cost-effective and environmentally beneficial. [17].

Evolution of Using RAP throughout History

Reclaimed asphalt pavement (RAP) is one of the most recycled materials globally, and its use in the paving industry has become more popular over time. Previous literature indicated that the recycling of asphalt pavements took place for the first time since 1915 in the USA[18].(Figure. 5) shows rudimentary techniques of recycling the asphalt pavement at various years throughout history [19]. However, the urgent need to reuse RAP in the construction of the new asphalt pavement began in the early 1970s due to the Arab oil embargo and the rise in the prices of crude oil and its derivatives [20].

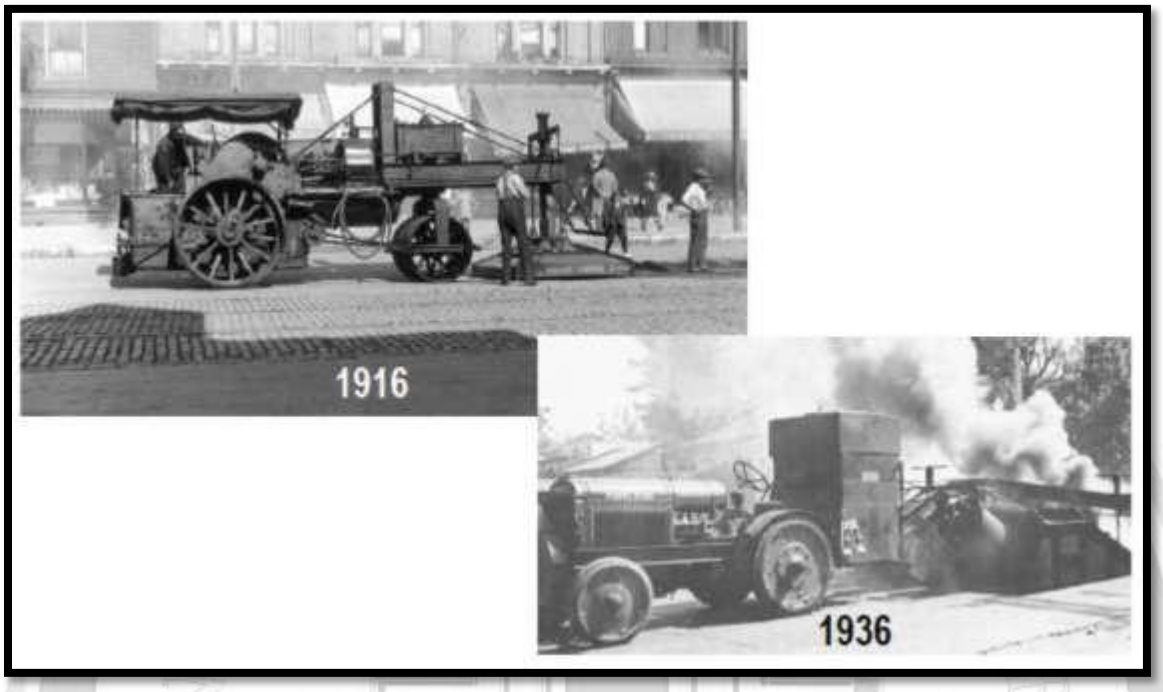


Figure (5) Recycling of Asphalt Pavement in Various years [19]

Determinants to the Increase of RAP Contents in HMA Mixtures

In year 2011, the (Federal Highway Administration (FHWA)), established a definition for asphalt concretes that possess a composition in which the quantity of recycled asphalt pavement (RAP) exceeds 25% of the total weight of the mixture. These compositions are classified as high content RAP mixture [21] **.** Many studies have shown the viability of manufacturing bituminous mixtures with elevated over 40% by weight or exceptionally high up to 100% by weight RAP. The adverse perceptions and practical challenges that constrain the prevalent practice from surpassing the average RAP composition of (15–30%) by weight in hot mix asphalt mixtures can be succinctly outlined in four - classifications pertaining to the caliber of the RAP aggregate, the production plants technological capabilities, the mix design methodology and the performance characteristics of the ultimate mixture encompassing (RAP).

Research Objectives

The current study examines the frontiers, The current state of the art, and the increasing trend of sustainable asphalt mixture studies using information area mapping and bibliometric analysis. These analytical techniques and methodologies cannot mitigate any biases and erroneous conclusions found in traditional review publications by employing a quantitative review methodology. As far as the writers' data permits t, This review is the first to use scientometrics. (on the topic of this study). To more accurately classify the state-of-the-art and recent advancements in the characterization of sustainable asphalt mixture

Data Collection and Employed Tool

The goal of Dimensions, an online resource that houses several research datasets from earlier studies, is to support scholarly and scientific study. It gives you access to a wide range of databases that serve as information sources for specialized study.. This allows users to search in-depth inside particular academic and scientific research subfields. Strong correlations between shared data are the foundation for all of these bibliometric approaches that present prior research Depending on the map's lines and the founder's nodes and intensity which group co-citing papers or authors who appear in the same article references according to the degree of connectedness between the annotated elements (authors, nations, references, and keywords) in the scholarly mapping [22].A statistical method for figuring out the direction and speed of development in any sector is scientific metric analysis. The website of the Dimensions was selected for the current study because it is a reputable source of bibliographic data and has been suggested by numerous researchers [23].

Results

Analytical Method

The field of library and information science gave rise to bibliometrics, which is now widely accepted and integrated for use in many other disciplines, particularly for quantitative analyses by researchers, institutions, and journals based on academic outputs. Numerous programming tools and packages, such as BibExcel, CiteSpace, Pajek, Gephi, Vos Viewer, and Histcite, have been created to conduct the bibliometric process. The VOSviewer was used in the development of visualization and bibliometric maps [24]. This software is mostly used for bibliometric network analysis, and it employs a single framework for both mapping and clustering. Three different kinds of visualizations can be created with VOSviewer: overlay, network, and density visualizations. We also carried out extra analysis using the R program "Bibliomatrix."[25].

after remove of all unnecessary document , 1438 publications were extracted from the Dimensions. Table (2) presents the application of Dimension categories to the received documents. About 54.52% of the total was made up of engineering, while the least appealing topics were physical sciences, philosophy, and religious studies. The articles' publication year is displayed in (Figure 6). The graph clearly shows the annual growth of publications, which is occurring at an exponential rate.

Table (1) Documents Detailing the Publications that Obtained Based on Dimension Categories

Categories on the (D)	Record Count	% of 1438
Engineering	784	54.520
Bulit Environment and Design	399	27.746
Chemical sciences	130	9.0403
Environment sciences	53	3.685
Earth science	23	1.599
Agricultural, Veterinary and food sciences	19	1.321
Commerce, management, touris and services	9	0.625
Physical sciences	6	0.417
Biological sciences	3	0.208

Information and computing sciences	3	0.208
Mathematical sciences	3	0.208
Human society	2	0.139
Psychology	2	0.139
Law and legal studies	1	0.0695
Philosophy and religious studies	1	0.0695

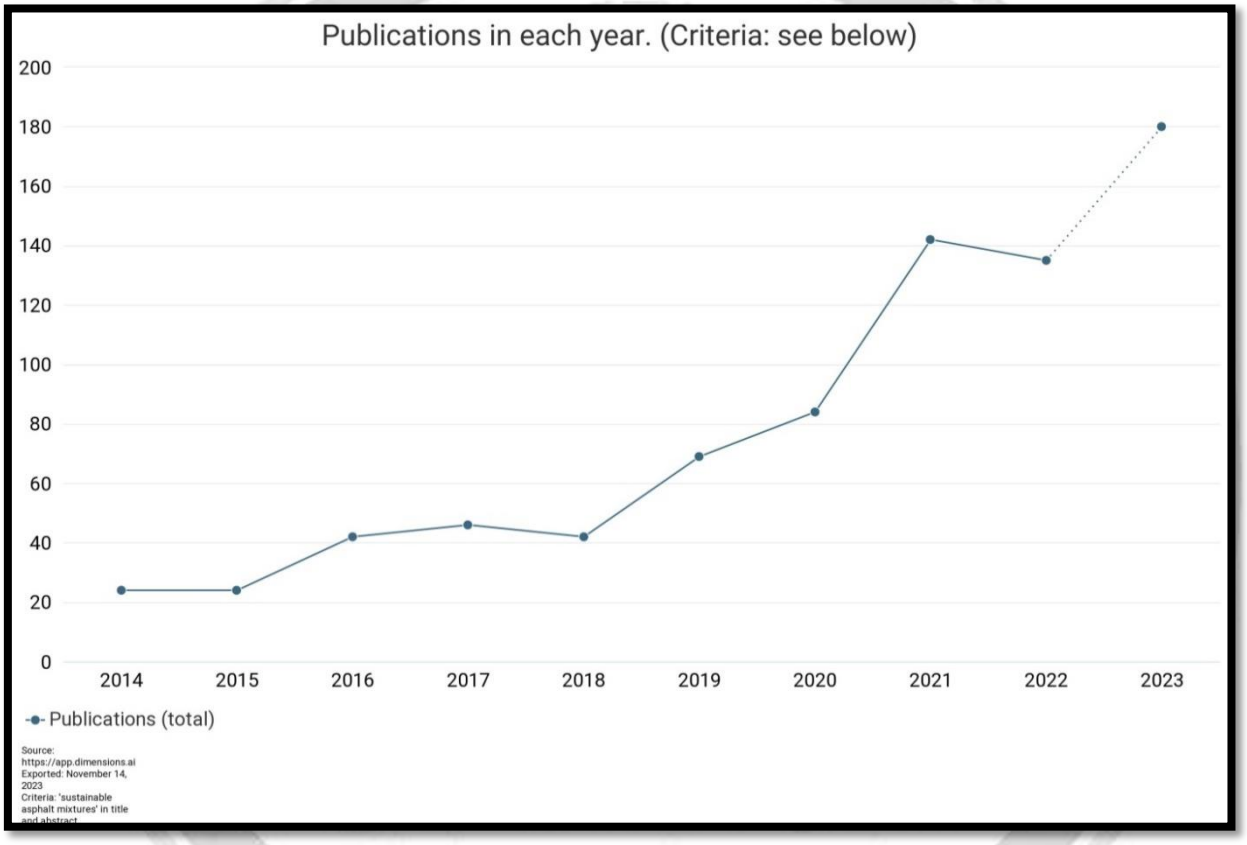


Figure (6) Research Publications Made Year-wise.

Country and Author Co-authorshipp

Table 2, lists the top 10 contributions made by countries and authors. China dominates in the number of publications with a total of 857 and is followed by saudi arabia (121 publications) and united states (263 publications). The top three authors with a high number of publications are the wu,and Shaopeng (25 publications), Amin, Muhammad Nasir (17 publications), and"Khan, Kaffayatullah (17 publications).

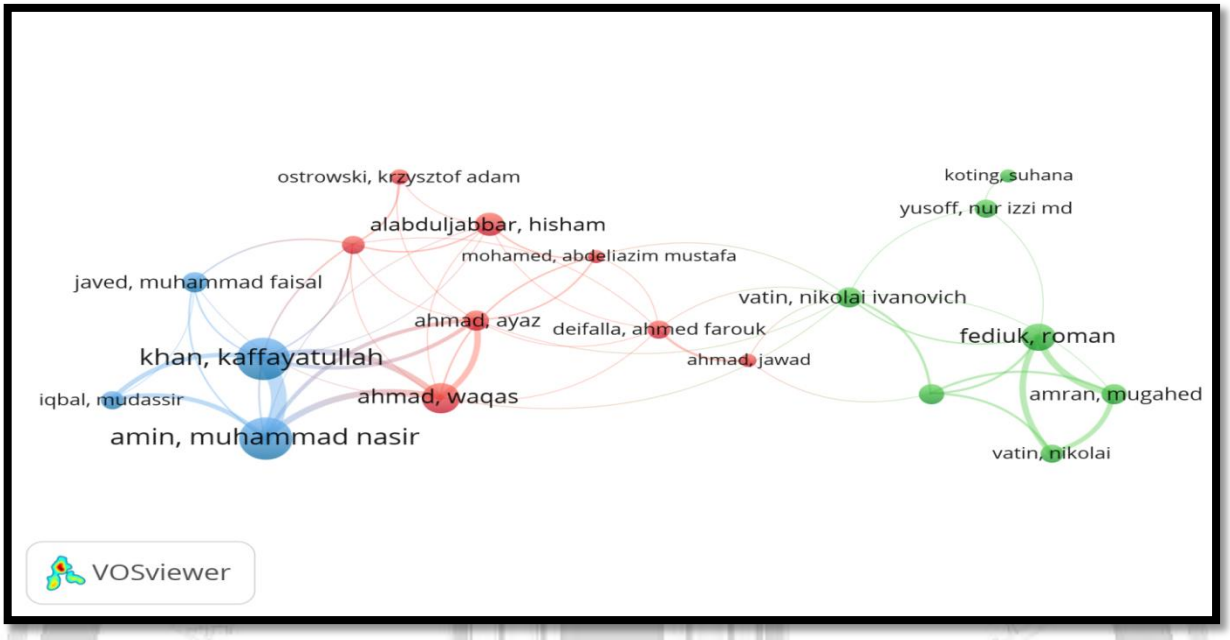
(Table 2) The Top Ten Contributions Made by (Countries and Authors) are displayed.

No	Country	Freq*	Authors	Freq*
1	china	857	wu, shaopeng	25
2	saudi arabia	121	amin, muhammad nasir	17
3	united states	263	"khan, kaffayatullah"	17
4	malaysia	116	giustozzi, filippo"	15
5	india	165	ahmad, waqas"	12
6	pakistan	73	"fediuk, roman"	11
7	united kingdom	103	Huang,jiandong	10
8	australia	99	Liu,quantao	9
9	egypt	50	Alabduljabbar,hisham	9
10	russia	56	Castro-fresno,daniel	9

Note: * Freq= Frequency

Coo-authorshipo measurment

A domain knowledge map of well-known authors' co-authorship networks might provide helpful foundational information to various institutions to support collaborative research teams. Such data can also be very beneficial to many scholars. Seeking new collaborators and publishers, and having the ability to assemble editorial teams data on co-authorship[26].(**Figure.7)** displays a map showing the most well-known writers who have written on sustainable asphalt mixtures, their collaboration, and their joint study. The degree of collaboration and participation among scholars is indicated by their proximity to one another or membership in the same organization. Different-sized and colored circles are used to represent and categorize the elements, while lines that show the relationships between the elements are used to connect the elements. Since the space between the items indicates the degree of connection between them, the thicker lines indicate the most effective communication between the pieces. The total strength of relationships with other writers that result from co-authorship is calculated. Those writers who have the most links overall are selected **.** As a result, there are (19 items) ,(3 cluster) networks, and (51 links) , and the circles are colored based on the clusters.



(Figure 7) The Author's Network- visualization Map

Country

With 10 items, 2 clusters, and 45 links, the network map in (**Figure. 8)** shows which nations publish the most research on sustainable asphalt mixture. First came the People's Republic of China, then by saudi arabia, united states , and Malaysia. These nations have offered a substantial body of study that aids in the creation of eco-friendly and sustainable asphalt mixture

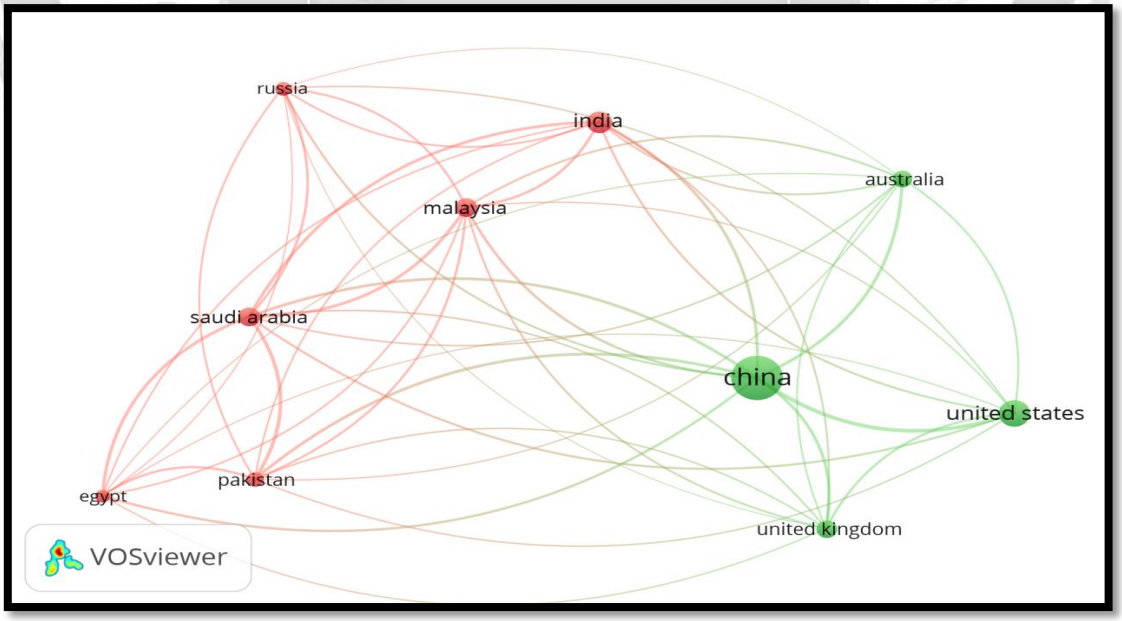


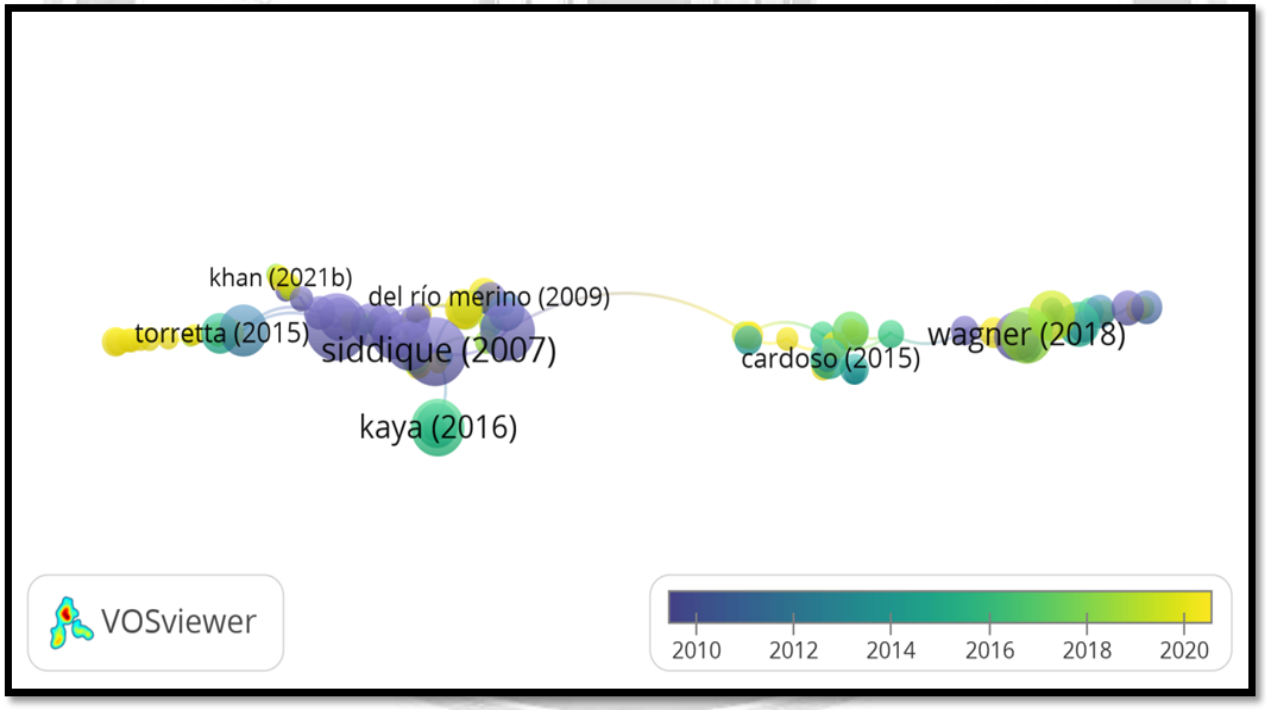
Figure (8) Map of the Countries Visualized Through a Network

Citation Analysis

The citation analysis demonstrated that it was done to identify primary research (documents, sources, nations, organizations, writers). The examination of frequently referenced document to identify the critical research domain is facilitated by the ability to recognize document citations and citation groups [27]. The main goal of this part is to identify clusters according to the most significant citations made by the scientists and publications. The journal title and the last name of the first author are used to identify the clusters, and the terms that were searched for are removed from the document's keywords, abstract title [27].

Using documentt ass a citation- unit

Forty was the minimal number of document citation required. There are 97 citations in the largest collection of related things. The analysis shows that there are 15 clusters. The most citations for the term "sustainable asphalt mixture" were fir st found in 2010, and **(Figure. 9)** displayed the top citation clusters identified by the first author's last name. Every cluster denotes a year-long surge in citations attributed to specific research groups studying the subject at hand.



(Figure9) Citations Network – Document

using a Source as a Citation Uni

There was scientific metric analysis done based on citation's source. based on the journal's title, which is used to quote a specific article. Out of the 240 sources, only 48 revealed connections between them. 198 linkages and a total of 43 groups appear to exist. The largest circles in (Figure.

10) show the materials with the largest circles, the source groups that obtained the most citations, and the most significant figure in the study field and its pace of growth.

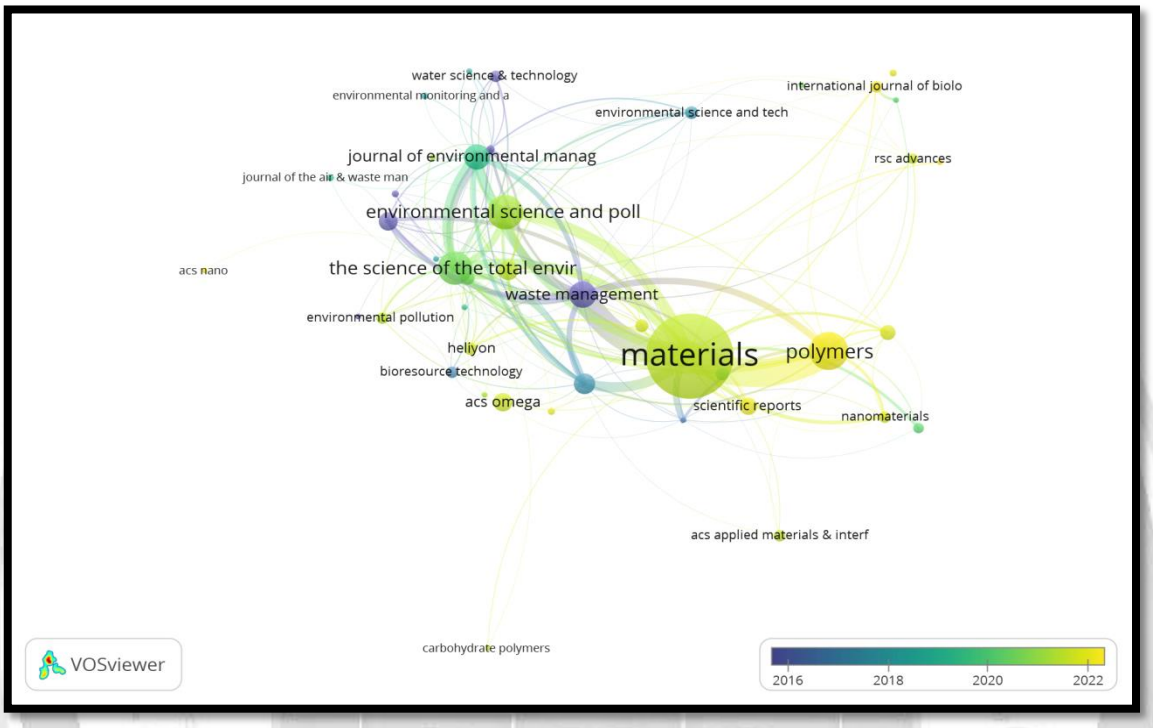


Figure (10) Citation Network – Source

Using Organizations as a Unit of Citations Analysiss

As an origin The total strength of the citation ties with other organizations for each of the 10 organizations will be ascertained. comsats university islamabad, with 896 citations and a total link strength of 248, and peter the great st. Petersburg polytechnic university, with 612 citations and a total link strength of 238, are the two organizations that have the highest overall link strength, They will be chosen**.**

Table (3) Most Organization

NO	Organization	Documents	Citations	Total link strengt
1	comsats university islamabad	26	896	248
2	peter the great st. petersburg polytechnic universit	29	612	238
3	prince sattam bin abdulaziz university	31	721	217
4	wuhan university of technology	55	944	192
5	national university of sciences and technology	15	444	146
6	far eastern federal university	11	402	138
7	shanghai jiao tong university	15	702	136
8	king faisal university	18	179	129
9	tongji university	35	757	124
10	southeast university	35	581	122

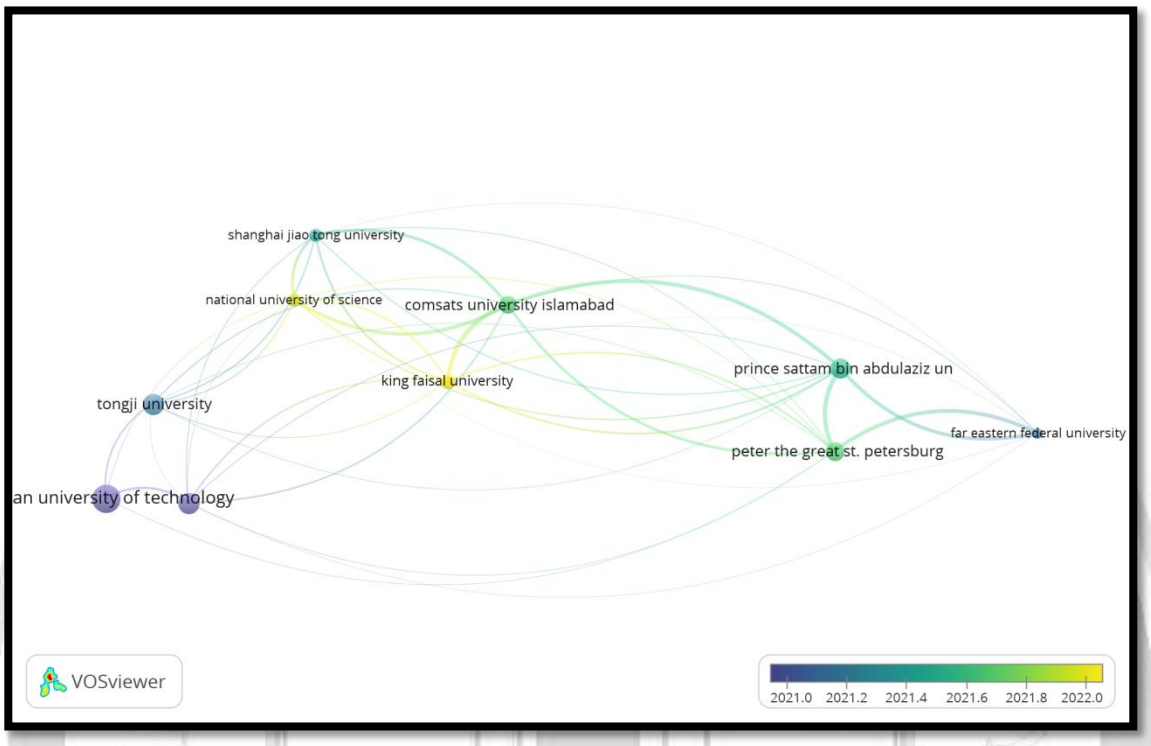


Figure (11) Citation- Network – Organization

Co-citation Examination

The author co-citation analysis , or co-citation examination, is one of the most widely used methods in scientometric studies [28]. This type of examination can aid in comprehending the process of specialization development [29]. Furthermore, the citation network may omit some significant articles, which makes the co-citation network superior [30].

Co-citation Cited Reference

Out of 114045 citations, 24 satisfied the criterion, making twenty the least number for the selected referenced source. (**Figure.12)** presents the entire study data results and indicates that the publications mentioning track geotechnology had a high number of citations**.** It is made up of 24 objects, 4 clusters, and 117 links. The links in the network depict the connections between nodes, while the nodes themselves reflect cited references as co-citations in the database..

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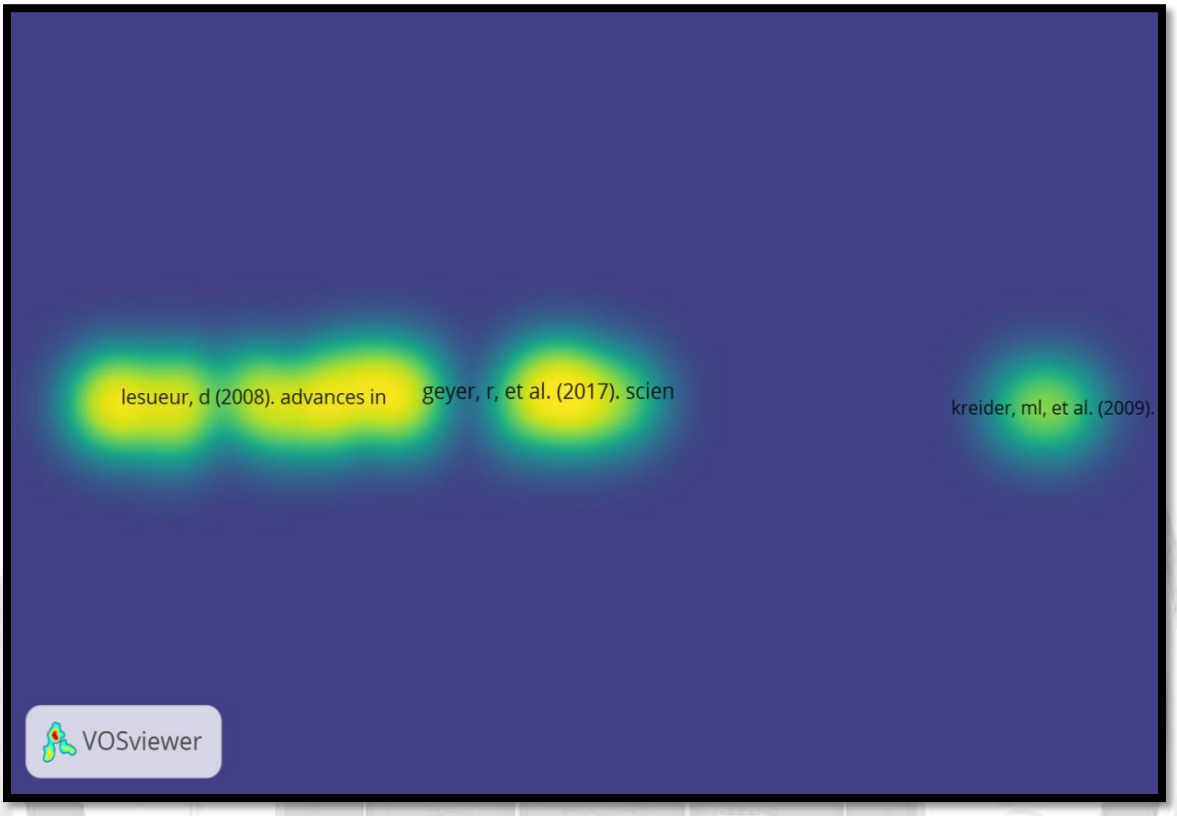

(Figure 12) Co-citation Cited References Density Visualization

Co-citation Source

Just 807 out of 9067 numbers were deemed to be the minimum, 22, as per the criteria. As seen in Figure 10, a net including 6 major clusters and 144038 linkages was created. Every group is a representative of the top publication that disseminates research on sustainable asphalt mixtures

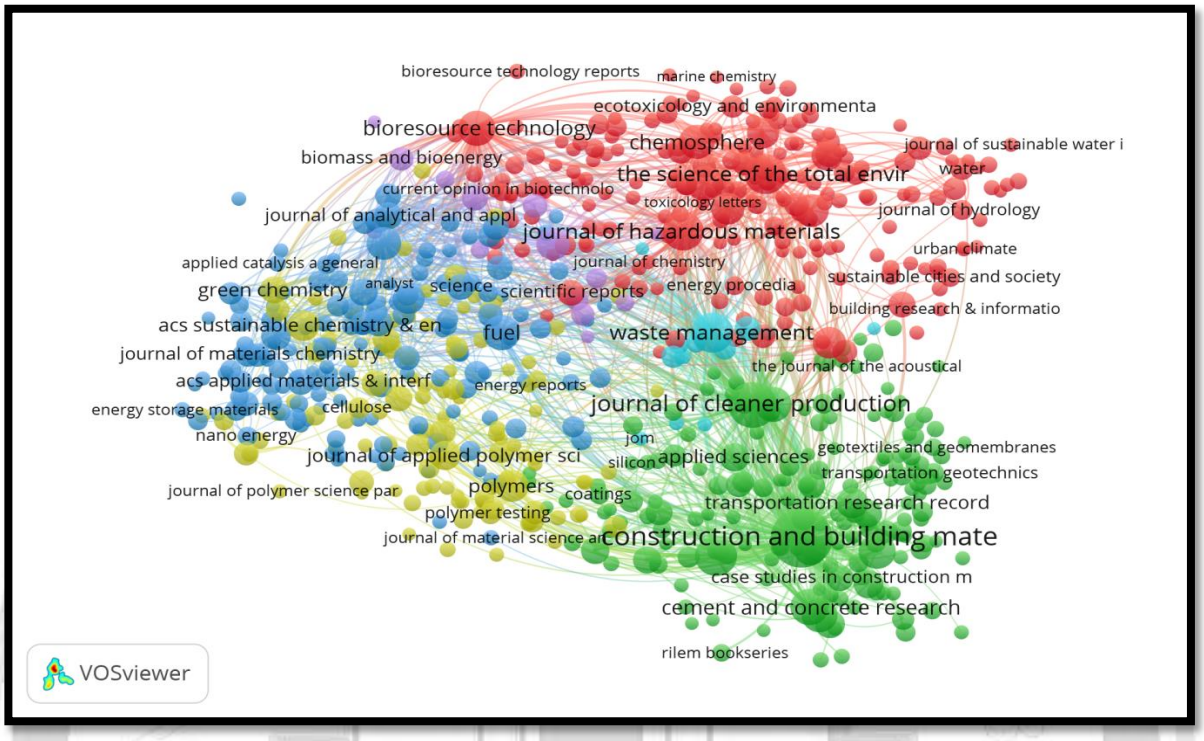

Figure (12) Co-citation – Source

Authors Co-citation Analysis

The cited references in this analysis need to be cited with at least 17 citations. Of 298516 sources, only 3783 satisfy the requirements. 1000 items, 9 clusters, 255581 linkages, and 2331628 total link strength are shown in (**Figure. 13)** the most co-cited author .

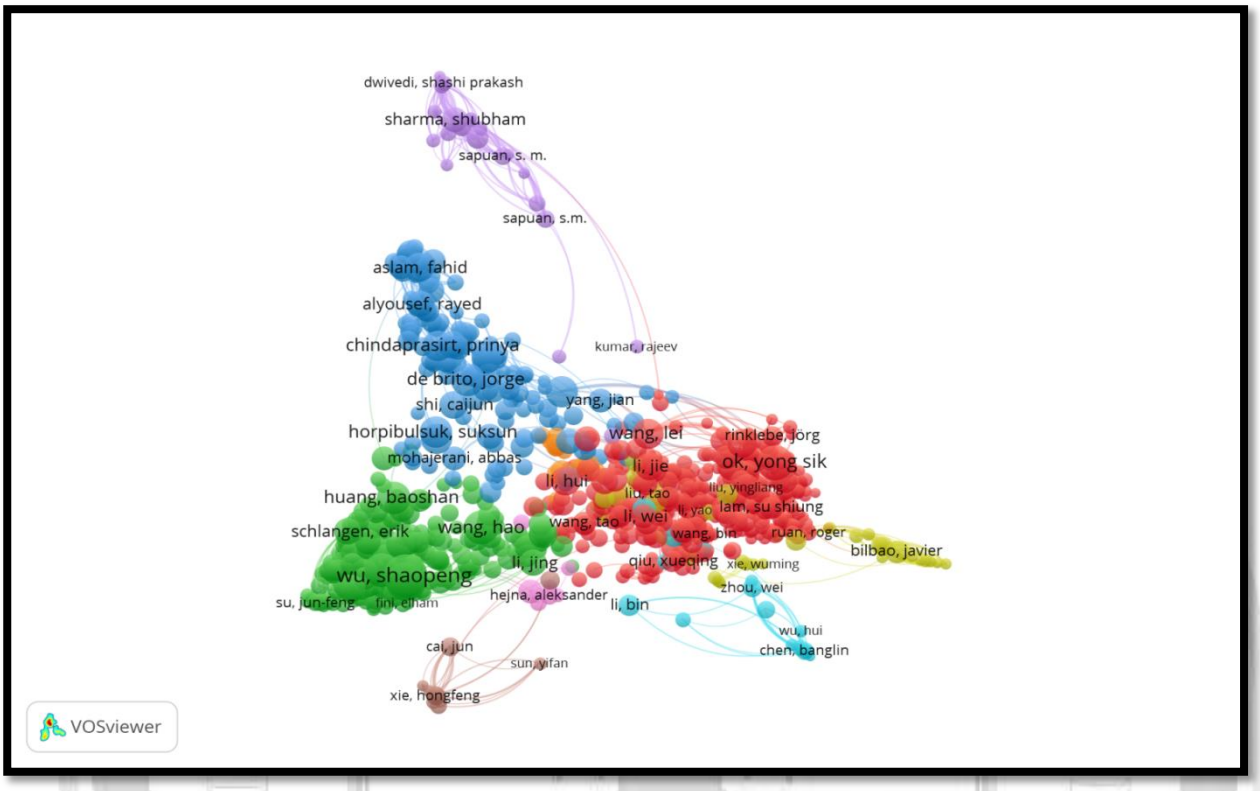

Figure (13) Co-citation Network - Author

Summary and conclusions

After reviewing the literature and using VOSviewer software to sustainable asphalt mixture , the following important conclusion may be drawn:

- Sustainable asphalt mixtures have emerged as a promising solution to address the environmental impacts associated with traditional asphalt pavements. By incorporating recycled materials, modified binders, and innovative production techniques, sustainable asphalt mixtures offer several benefits, including reduced energy consumption, decreased greenhouse gas emissions, and improved durability.
- The most influential scholars who have written about sustainable asphalt mixtures, their connections to them, and the degree of their collaboration were all determined using the VOS viewer tool. These researchers included : WU, Shaopeng, Amin, Muhammad Nasir, Khan, Kaffayatullah" Giustozzi, Filippo, Ahmad, Waqas". Additionally, it determined which countries

were, in comparison to the United States, Malaysia, Saudi Arabia, the People's Republic of China, and Saudi Arabia, the most important in the spread of knowledge on this topic. Universities working together to conduct research on sustainable asphalt blends include: The Comsats University Peter the Great St. Petersburg Polytechnic University and Islamabad.

- Consequently, this study provides a roadmap for scholars to comprehend the foundational ideas surrounding the interaction between sustainable asphalt mixtures.
- Innovative production techniques, such as warm mix asphalt technologies and energy-efficient plant designs, help minimize energy consumption and greenhouse gas emissions in the asphalt production process. These techniques also provide opportunities for the use of renewable energy sources, further reducing the environmental footprint of asphalt manufacturing.
- Sustainable asphalt mixtures present a promising and environmentally responsible alternative to traditional asphalt pavements. Through the integration of recycled materials, modified binders, and innovative production techniques, they offer improved performance, reduced environmental impact, and enhanced long-term sustainability in the construction and maintenance of road infrastructure.

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الخلطات الاسفلتية المستدامة : تحميل متري علمي ومراجعة ببليومترية

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الخلاصة:

الآثار البيئية لبناء طريق جديد عديدة وتشمل استخداما كبيرا للمواد والطاقة. بالإضافة إلى ذلك ، كانت هناك زيادة ملحوظة في سعر النفط الخام ، المصدر الرئيسي للموثق البيتومين ، في السنوات الأخيرة (وعلى الأخص في 2001-2008). وقد ارتفعت تكلفة مخاليط الأسفلت ككل نتيجة لذلك. يجب تنفيذ التدابير ذات المؤهلات القوية للاستدامة على نطاق واسع لمكافحة الزيادات في الأسعار وتشجيع الأنشطة المستدامة. قد تصبح أعمال رصف الأسفلت أكثر استدامة وفعالية من حيث التكلفة من خلال إنشاء مواد وتقنيات جديدة تشمل القمامة والموارد المعاد تدويرها والمكونات الأكثر خضرة في دورة إنتاج خليط الأسفلت

تظهر مخاليط الأسفلت المستدامة متانة محسنة وعمر خدمة أطول ، مما يقلل من الحاجة إلى الصيانة وإعادة التأهيل بشكل متكرر. هذا يؤدي إلى توفير التكاليف وتقليل تعطيل حركة المرور. الغرض من هذه الدراسة هو تحديد الدول والمؤسسات التي نشرت أكبر عدد من المقالات حول موضوع مخاليط الأسفلت المستدامة ، وكذلك تحديد وتجميع الأوراق البحثية الأكثر بروزا باستخدام "Dimensions" وتحليل البيانات باستخدام برنامج (VOS viewer software) . بالإضافة إلى ذلك ، تم القيام به لمعرفة المزيد عن تعاون الكتاب .

الكلمات الدالة:- مخاليط الأسفلت المستدامة، البيئة، مواد صديقة للبيئة، اعادة تدوير.