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Subgrade Stabilization of Railway Track: Literature Scientometric Analysis

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Abstract

The material layer where the ballast and sub-ballast layers lie is known as the subgrade. Since the subgrade is a critical component of the track construction and has contributed to track failure and the deterioration of track quality so many of researcher conducted much research on this layer. The purpose of this study is to comprehensively evaluate and depict the current state of research on railway track. Utilizing the VOS viewer software, the analysis was done using the Web of Science website by looking at the prior study conducted on subgrade of rail track. Using the keyword co-occurrence analysis feature, this study looked at the frequency of occurrence of keyword, "subgrade" based on a total of 456 publications with "subgrade" in the keywords, abstract, or title, the search result successfully identified three groups using the cluster analysis method. Citation burst analysis was used in the study to examine the growth trend in the field of subgrade and show how research on railway track has changed over time. In order to more accurately categorize the present state of affairs and upward trend in railway track, this study is distinctive in that it gives the reader complete information on the body of previous research on subgrade investigations. A review of previous studies showed that the stabilization of the subgrade will enhancing engineering qualities, 10% cement content for railway track subgrade was the ideal ratio for some type of soil.

Keywords: Scientometric analysis, Railway track, VOS viewer

1. Introduction

Nowadays, trains became the transport mode of choice because it can carry heavy goods, and passengers for long distances [1]. Therefore, there have been urgent demands on the development of railways to enable the use of fast and heavy trains as many of the world's railway lines are 60 to 100 years old, and most of these cannot be used for fast trains due to issues associated with the critical velocity of the train [2]. The subgrade is the basis for the track

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structure. The chief role of the subgrade is to offer a stable basis for the track construction and so the subgrade has an important influence on track performance and maintenance. Recent studies illustrated the importance of the subgrade in the design of fast-moving trains and how the shear wave velocity of the train controls the critical velocity of the train regales of the thickness of the ballast layer or the weight of the train. Thus, the subgrade sometimes needs to be stabilized to enable using faster trains. Therefore, in order to understand the current state of the art regarding the railway subgrades in the literature, it is required to have a thorough literature review that summarizes the past studies on the topic and thus, illustrates the gaps in knowledge. Thus, the aim of this study is to conduct a bibliometric analysis to understand the current state of the art on this topic. Bibliometric analysis is a statistical, quantitative technique for examining the links between literature and information in books. It was discovered after using this strategy, it was possible to accurately identify the key research trends in a specific area of study and foresee future directions. Indicators such as citation and citation per document are employed in this methodology to help determine the final assessment of the research result in terms of the nations, organizations, and authors. Scientometric is a branch of bibliometric research that uses knowledge domain visualization (KDV) to statistically review scientific literature. KDV makes use of a number of technologies, including CiteSpace, VOSviewer, Histcite and Gephi, and Bibexcel. These technologies, such as co-authorship, cooccurrence, citation, and co-citation networks, can offer a combined and comprehensive knowledge map. KDV is a comprehensive strategy that uses visualization analysis to reveal the linkages and structural links of the information in the method of comprehensible drawings.

2. Research objectives

As stated earlier, the current study uses bibliometric analysis and information area mapping to examine the state of the art, the frontiers, and the upward trend of subgrade railway studies. By using a quantitative review methodology, these analytical tools and approaches could reduce any potential biases and inaccurate conclusions identified in the traditional review papers. This is the first scientometric review on this study subject, as much as the writers' data allow. In order to better categorize the current state of art and current developments in the area of rail track materials characterization:

1. The earlier studies (from 1990 to 2021) that examined the subgrade of railway were evaluated and debated.
2. Insightful suggestions are also given based on the most significant studies to direct academics and practitioners to focus more on the newest and most fascinating themes.

3. Effects of train load on subgrade

Defects in subgrade are mostly due to track surface irregularities. Due to the usage of excessive axle loads and velocity on the train, subgrade breakdown occurred, delaying train times, and raising maintenance costs [3]

Many types of subgrade failure related to train loading depend upon failure mechanism are:

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• Massive shear failure: which failure caused by the train's weight, weak soil, and higher water content

• Progressive shear failure: which occurs at the surface as a result of the cyclic overstressing of the soil. In this kind of failure, the subgrade's surface gradually bulges upward and outward while taking the easiest possible path.

• Mud pumping: The movement of fines and mud pumping enters the ballast and reduces its capacity to carry load. Over time, this causes the degradation of track geometry and the development of wet areas.

• Excessive subgrade failure: The ballast pocket is typically the outcome of the issue of an excess amount of settlement by plastic deformation.

• Attrition: this type of failure can be caused by interaction between ballast &subgrade, rocks that are clay-rich or have oils and presence of water.

4. Effect of stabilization on subgrade

Construction that built on soil with strength changes was conditionally more prone to failure. Substantial defects are commonly seen in soft to very soft clay soils as these kinds of soils are sensitive to deformation and has low shear strength leading to structural destruction during the execution and throughout the life of the project. Thus, modification or stabilization or both of them were routinely used to improve such soils. Modification technique relay on mixing soil with another or replacing the original one, while durability and strength of the soil usually improved by soil stabilization treatment method to make it more suitable for construction. Lime, cement, and waste products like (fly ash, slags, silica fume, etc.) were the most common stabilizer materials that used for subgrade pavement [4]. Many studies have discussed the effect of stabilization on the mechanical and geotechnical properties of the soil and employed the stabilized soil in different civil engineering applications [5]- [8] . [9] used a finite element (FE) model (2D plaxis program v 8.2) to evaluated properties of stabilized and non-stabilized subgrade layer of pavement section ,by using two type of stabilizer (lime and silica fume as combination while the second were lime and Nano silica) the section of pavement was subjected to deferent load from (50 to 700) kpa with subgrade thickness layer (20 to 50) have been stabilized, the result shows that increasing the traffic load will increase the total stress and the vertical displacement but when using stabilizers they reduced. [5] used 3D finite element to analyze structure properties' and mechanical behavior for soil base stabilized with cement, the pavement filling and load were emulation and to describe the behavior between each layer they use a contact model, the result shows that the bearing capacity can increase and the tensile stress at the bottom of the pavement can be prevented. Plaxis 2D finite element program had been used by [8] to determine the deformation characteristics of cement modified soils. They found that the vertical deformation of soft soil increased when the percentage of cement increased and also show the lowest deformation happened when they used 15% of cement stabilization. [7] study the effect of stabilized subgrade on the pavement responses by using 2D finite element; the stabilizer

was hydrated lime 7% with nano slag 3% as combination the study shows that the total stress and vertical displacement were decreased.

5. Data collection and employed tools

Scientometric analysis is a statistical tool of publications to determine the direction and pace of development in any field. The database of research documents was taken from web of science core collection. The web of science website was chosen for the present investigation since it is one of the famous sources of bibliographic information and were suggested by a number of studies [9] - [12]. Scientometric analysis and the creation of maps based on network data, as well as the visualization and exploration of maps based on various types of network data, were carried out using the VOS viewer program. This program was produced by [13]. Topic is searched in term of "subgrade", the search covered authors keywords, title, and abstract for every documents. In addition, only the studies related to railway engineering were considered. Publications from 1990 to 2021 were covered in the search. In addition, the covered indices are SCI-EXPANDED, SSCI, CPCI-S, BKCI-S, and ESCI. After clearing all the unrelated documents, 456 publications were retrieved out of the web of science. Table 1 shows how the obtained documents were categorized using the WOS categories. Engineered and civil documents made up about 66% of the total, while the least interesting in the topic were (Computer Science Interdisciplinary Applications, Engineering Environmental, Mechanics, Materials Science Characterization Testing, and Instruments Instrumentation). The year of publishing of the articles is shown in Figure 1. The figure makes it obvious that publications are growing exponentially each year.

Table 1 Records of the publications that were retrieved according to WOS categories

Web of Science Categories	Record Count	% of 456
Civil Engineering	302	66.228
Geological Engineering	223	48.904
Multidisciplinary Geosciences	116	25.439
Transportation Science Technology	91	19.956
Construction Building Technology	83	18.202
Multidisciplinary Materials Science	65	14.254
Mechanical Engineering	49	10.746
Transportation	25	5.482
Computer Science Interdisciplinary Applications	22	4.825
Environmental Engineering	10	2.193
Mechanics	10	2.193
Characterization Testing Materials Science	5	1.096
Instruments Instrumentation	3	0.658

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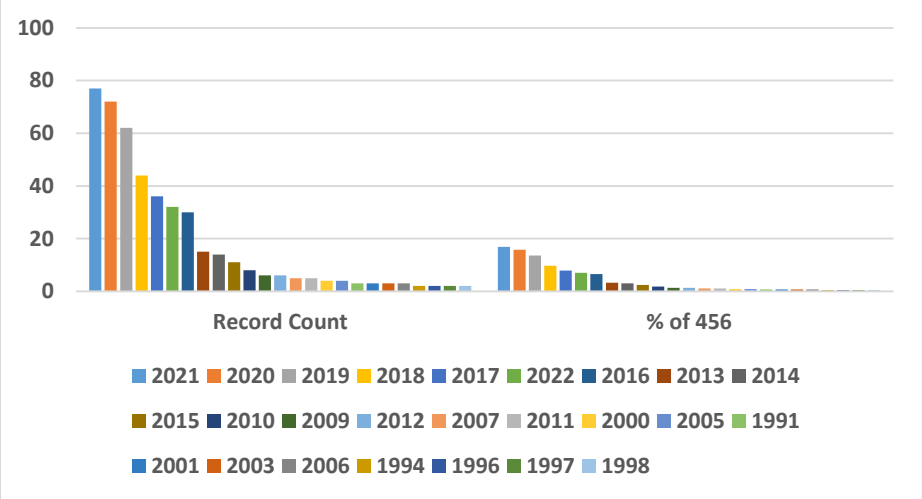

Figure1. Research publications made year-wise

6. Co-occurrence – keyword analysis

The bibliometric method is utilized to map the research field [14]. Generally, to know the most top 10 keywords used in railway as shown in **Table 2**. The minimum number of keywords occurrence in most research was selected to be 20 as a boundary condition. The result showed that 50 keyword met the threshold out of 2802 keywords. This examination was used in this study to map the revolution trends of the topic that correspond to subgrade of railway track. This analysis enveloped all the available keyword in the articles and the lowest number of occurrence of keywords chosen to be 5, as a result 137 met the threshold out of 1729 keywords. The keywords "behavior, subgrade, track" have the great number of occurrences 106, 68 and 86, respectively and total link as 575, 350 and 470 as shown in **Figure 2**. In regard to time the progression of the same keyword, interestingly (railway, model, behavior, and deformation) are the major keywords from 2017–2021, purple color was covered in 2017 while yellow one for 2020 as illustrated in **Figure 3** that shows the keyword occurrences - overlay visualization with average citations. It is of value to mention that **Figure 2** and **Figure 3** include 6 clusters, total strength 5301, and 2612 total link.

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Table 2 Most co-occurred author's keywords

id	Keyword	Occurrences	Total link strength
1	model	129	190
2	dynamic-response	110	135
3	track	97	149
4	dynamic response	95	88
5	prediction	93	153
6	behavior	88	112
7	ground vibration	77	103
8	system	72	112
9	railway	68	96
10	high-speed railway	66	102

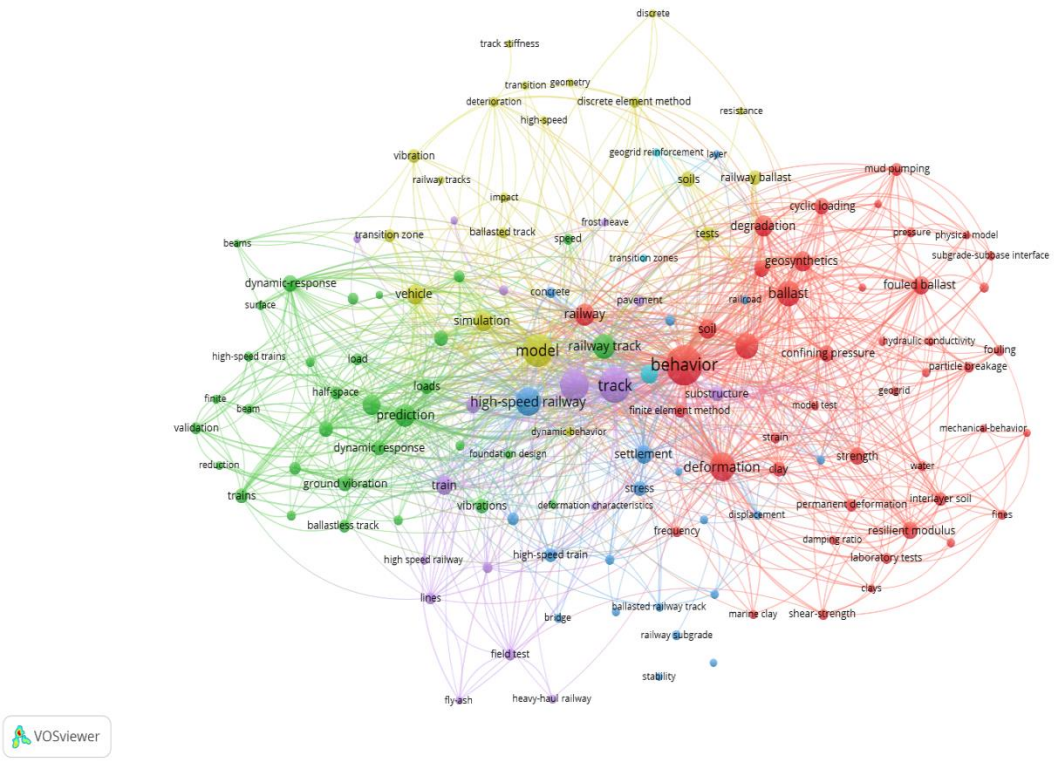

Figure 2. Co-occurrence keyword Network Visualization

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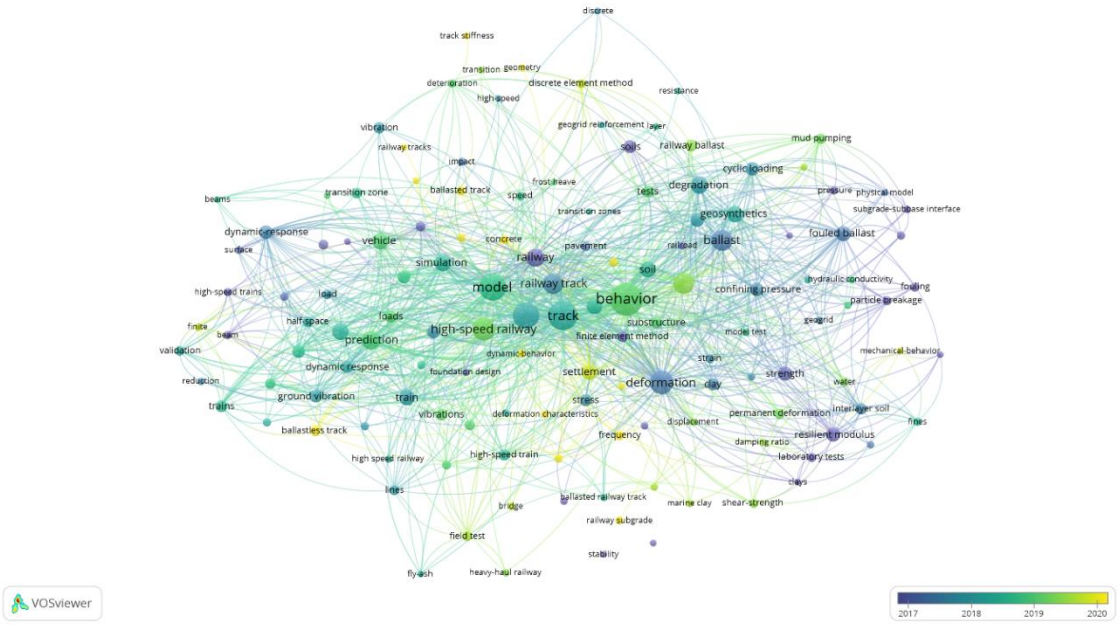

Figure 3. Keyword Occurrences - Overlay Visualization with Average Citations

7. Citation analysis

To determine the major research papers, sources, and nations, a citation analysis was carried out. Analyzing the greatly cited paper to determine the crucial study area is made easier by identifying document citations and citation groupings.

7.1. Using a document as a citation unit

The minimum number of citations of a document take as 10, only 197 out of 456 met the threshold. The largest citation was for [15] who investigated the plastic deformation for fine-grade subgrade soils. Forecasting cumulative plastic distortion for fine-grained subgrade soils under cyclic loading has been improved upon using current techniques from the literature. The prediction model accounted for deviator stress. A method is suggested for taking both several levels of deviator stresses and multiple soil physical states into account. Soil static strength was considered to take into account the physical state of the soil as determined by the dry density, soil moisture content, and soil properties. Regression analysis of publicly available test data in the literature was used to determine the values of the material parameters for the prediction model. To investigate the influence of soft soil subgrade on track performance under repeated large axle loads, a railroad test track with soft subgrade was built Vicksburg Buckshot clay, which has a high moisture content, was used to achieve the low stiffness of the subgrade. Under repeated strong axle loads, there was a significant development of subgrade plastic deformation. The test findings were consistent with the forecast of subgrade plastic deformation for the specified subgrade and traffic circumstances.

On the other hand, [16] has the second most cited document who studied the effect of fouling on ballast strength and stability. While [17] ranked third with the most cited research in their study "Transition of Railroad Bridge Approaches", their study was to determine the variables that may contribute to or hasten performance issues with bridge approach or track changeover, and develop and assess suitable mitigation strategies. [18] in their research "Full-scale field tests on geosynthetic reinforced unpaved roads on soft subgrade" ranked fourth. [19], [20] ranked fifth and sixth, respectively. The analysis showed that 14 cluster and 487 links as shown in Figure 4.

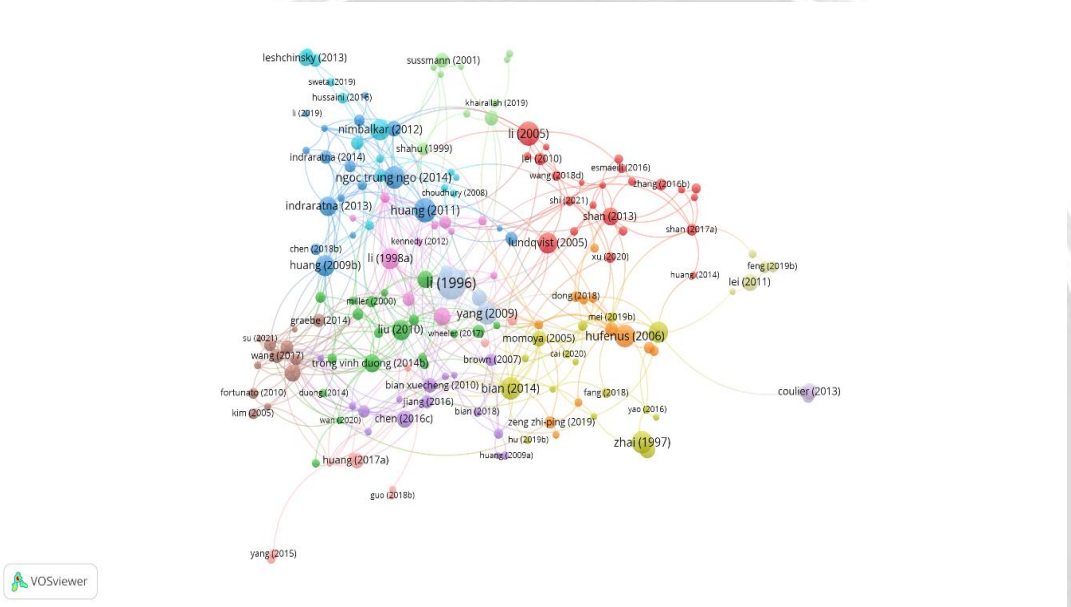

Figure 4: Citation network – Document

7.2.Citation organization

In this section, the most cited organizations were searched, the least number of document of an organization was taken as five, forty-one number of organizations met threshold out of 405 average citation was greatest in University of Massachusetts as 53.88 and University of Southampton 37.38, while University of Southwest Jiao Tong in China which belongs to cluster 2 out of 5 clusters has the greatest number of documents as 28 in 2019.

7.3. Citation country analysis

In regard to the number of countries was one and smallest number of citations as three, 39 countries met the threshold out of 47. China has the great number of documents as 189, 54 total strength and 12 link, while Thailand has largest number of research in 2021.

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8. The network of co-authors

Creating and analyzing an area information drawing of the co-authorship nets of eminent authors might serve as a helpful starting point for different institutions looking to develop collaboration amongst distinct study teams. Additionally, such data can help lone students locate possible collaborators, and publishers can construct editorial teams using co-authorship findings [21]

8.1. Co-authorship authors

Least number of papers of an author was considered as 2 to calculate the total strength link between the author and other authors, the study in Figure 5 illustrated density visualization which showed that 286 of 1210 writers met the threshold. The meeting point in Figure 6 stands in for the authors, the size of the nodes denotes the quantity of publications, and the interconnections between the nodes denote the relationships among authors that imply co-authorship. The heaviest cluster of linked things consists of 16 items which belong to cluster number 1. The two figures contains 113 meeting points, 12 clusters, 259 links, and the full link strength was 460.

8.2. Co-authorship country analysis

The co-authorship network is built on the origin country of the co-authors' addresses. Only 14 of the 47 nations met the boundary requirements, which called for a minimum of five documents per nation. According to Figure 7, there are 8 connected nodes in the largest set. China, Australia, and USA, have the biggest document, correspondingly. It has been discovered that there is a significant co-authorship relationship between China and USA as well as between Australia and England.

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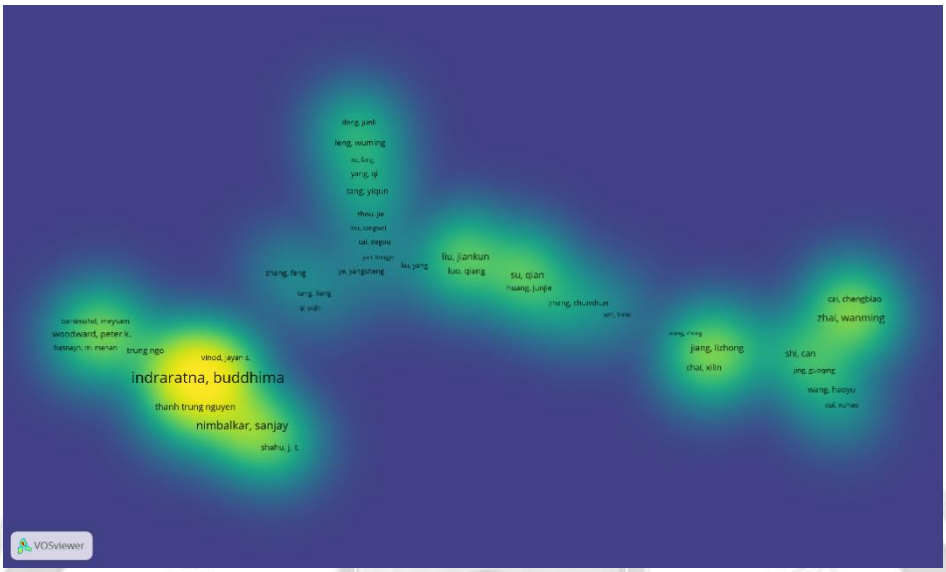

Figure 5. Author– Co-authorship density Visualization.

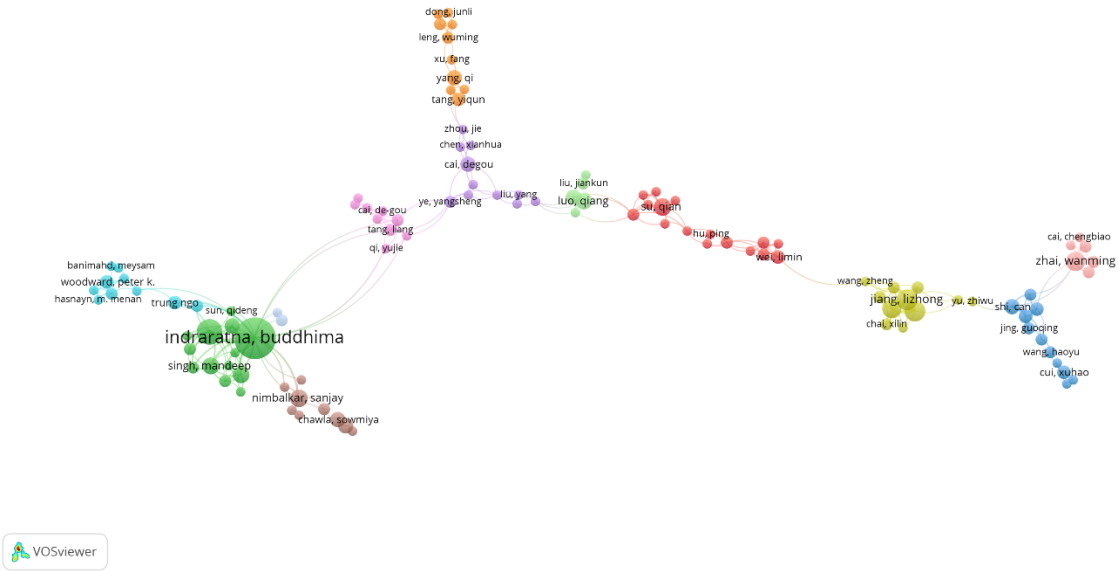

Figure 6. Author– Co-authorship network

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8.3.Co-authorship organization analysis

Co-authorship analysis was carried out to identify the density of collaboration amongst the research organizations for subgrade studies. The co-authorship network's knowledge domain map, taking the organization into account, as shown in Figure 8. The analysis required minimum of 5 documents of an organization. Only 41 of the 405 administrations met threshold. In addition, there are 7 clusters, 74 links, and the full link strength is 168. From the results it is found that University of Southwest Jiao Tong has the highest number of documents, which is equal to 40 and total link strength 16.

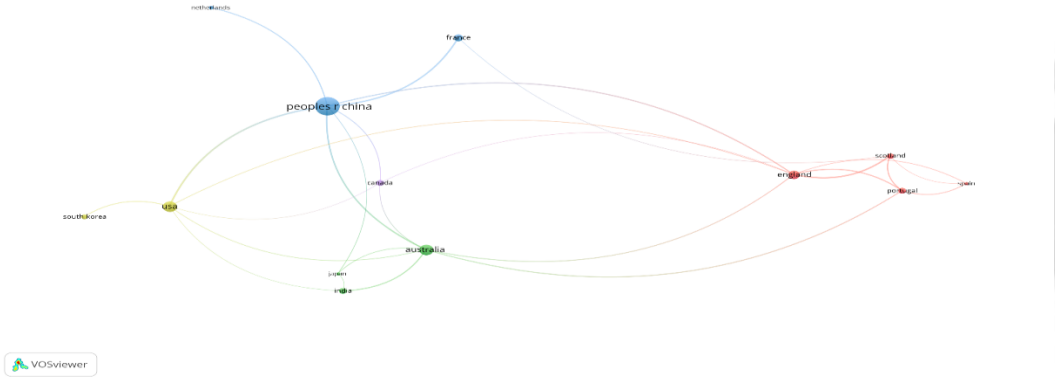

Figure 7. Network of co-authors by country

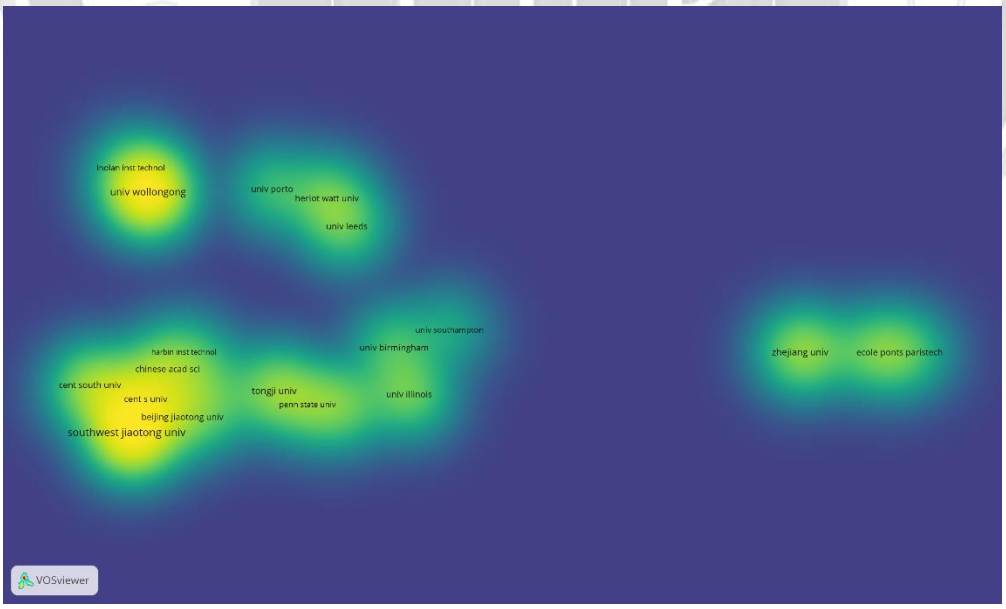

Figure 8. Co-authorship Organization density visualization.

9. Co-citation examination

Among the most popular techniques in scientometric investigations is co-citation examination, specifically the author co-citation analysis [22]. This kind of analysis can help in understanding how specialization development works [23]. Additionally, the co-citation network is superior to the citation network because the latter may leave out some important publications [24].

9.1.Co-citation cited reference

Smallest number of citations for the cited source chosen as twenty, 37 met the threshold out of 9709. The overall studied data results are displayed in Figure 9 which shows the studies that mentioned track geotechnology had a lot of citations. Ground vibrations were studied by several authors like Hall (2003), Madshus (2000), and Takemiya (2005) which belong to cluster 1 out of 4. Deformation behavior was studied in cluster 2.

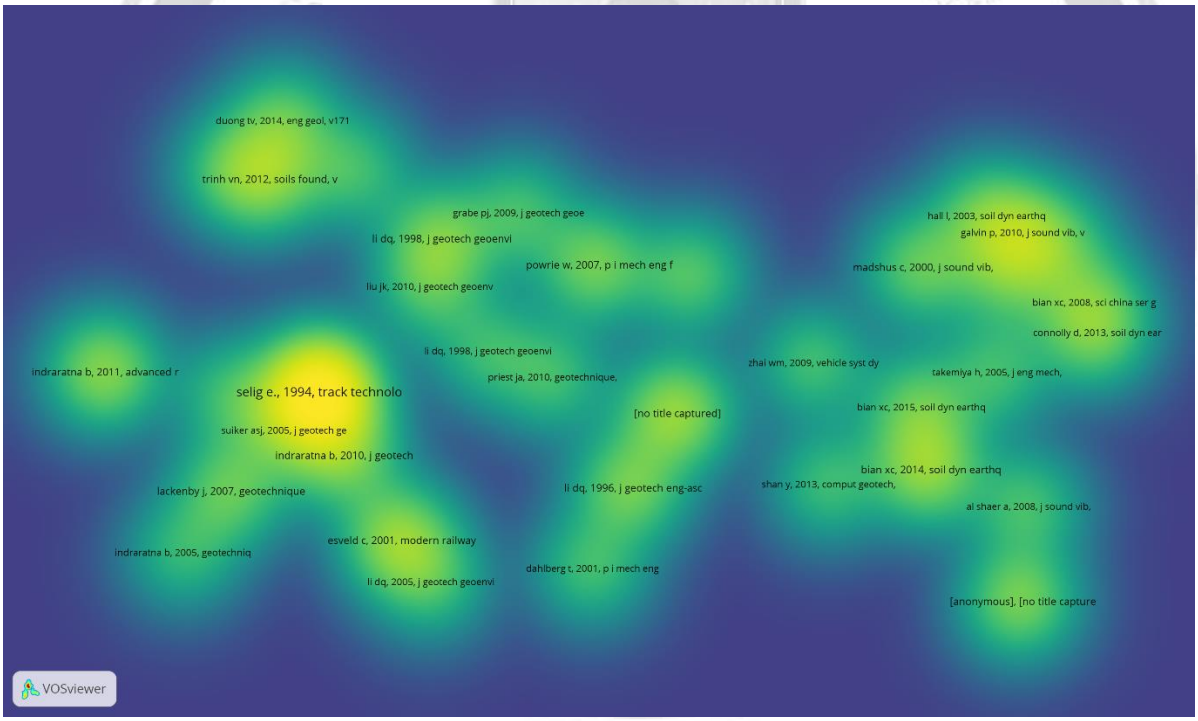

Figure 9. Co-citation cited reference density Visualization.

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9.2. Co-citation source

Minimum number was considered 20, only the 83 out of 4058 met the threshold. A net with 4 main clusters and 2910 links was produced as shown in Figure 10. Each group represents the leading journal that published paper on topics relating to subgrade and railroad tracks.

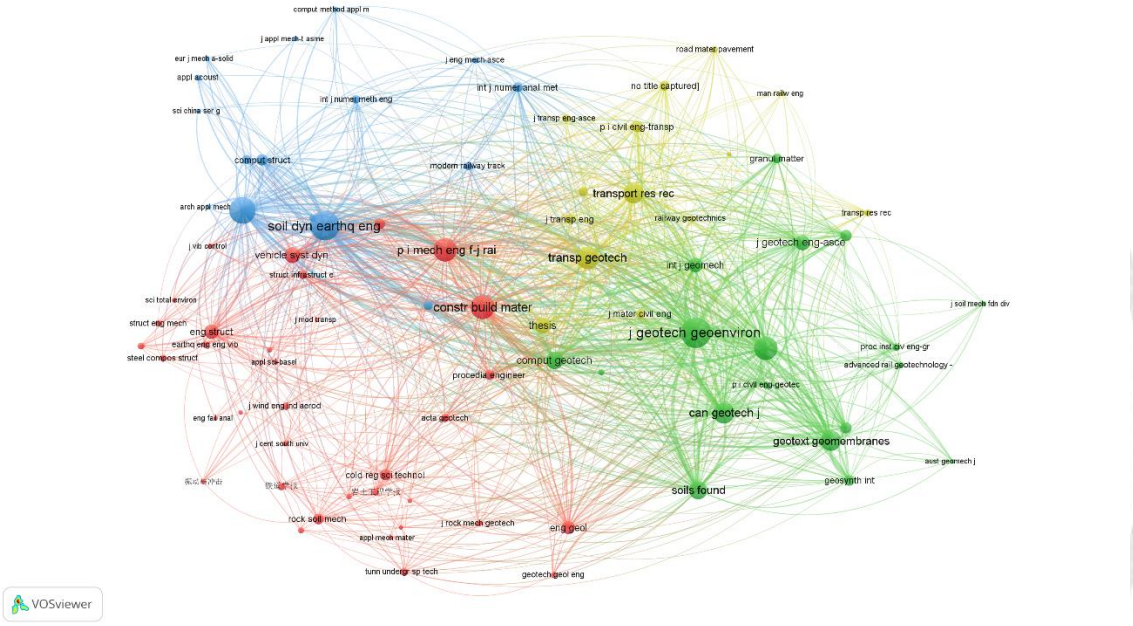

Figure 10. Co-citation - Source

9.3.Authors- co-citation analysis

In this examination the least number of citations for the cited reference was taken to be twenty, 98 out of the 5402 met the threshold. As shown in Figure 11 the most co-cited author is Buddhima Indraratna.

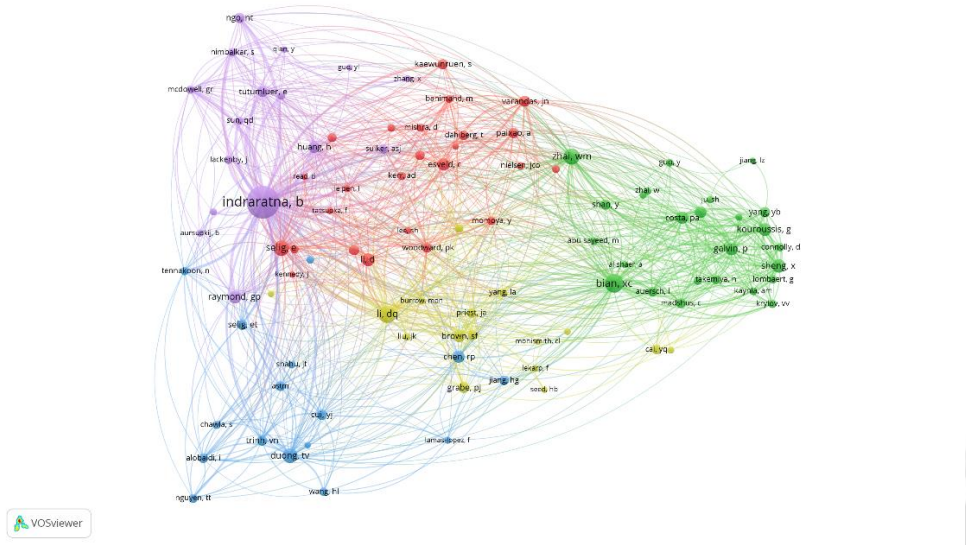

Figure 11. Co-citation network - Author

10. **Summary and conclusions**

The following significant finding may be made from a review of the literature utilizing VOSviewer software on subgrade investigations for railway the findings indicated that:

1. The majority of the co-occurring keywords had to do with the subgrade of rail track were behavior, railway track, model and high-speed railway and other keyword.
2. The citation burst analysis can be used to estimate the research scope for subgrade. The citation burst analysis for the term "subgrade" is covered in great detail.
3. The source of the most citations a publication has received in relation to the keyword "subgrade" is also mentioned. Journal of Transport geotechnics, Journal of Construction & Building Materials, Journal of geotechnical and geoenvir, soil dynamic and earth quick engineering and proceeding of the institution are the 5 main journals with the maximum number of citations that offer the user adequate data for literature-based, high-quality research papers. Additionally, a co-authorship network that details the development of subgrade research is included in this article.
4. The ideal cement content for road base and railway track subgrade has been determined to be 10%, which is sufficient to meet the demands for both strength and durability.
5. 7% hydrated lime with nano slag 3% as combination were sufficient to decrease the total stress and vertical displacement.

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It should be mentioned that the keywords used in the title, main body, and abstract were the basis for the current scientometric analysis. However, the scope of this investigation did not cover article structure. It is common knowledge that the structure of an article describes the research influence that can offer a rich understanding of the study's issue. Another drawback is the length of the analysis, which could affect some of the findings of this study in future research. Given that the current analysis covers the years 1990 to 2022, this disadvantage could not matter much in the near future.

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تثبيت الطبقة السفلية لمسار السكة الحديد: التحليل السيانتومتري للدراسات السابقة

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الخلاصة

تُعرف طبقة المواد التي تقع فيها طبقات الصابورة الفرعية أيضًا بأسم الطبقة السفلية. نظرًا لأن الطبقة التحتية هي عنصر حاسم في بناء المسار وساهمت في تتبع الفشل وتدهور جودة المسار ، فقد أجرى العديد من الباحثين العديد من الأبحاث حول هذه الطبقة. الغرض من هذه الدراسة هو التقييم الشامل وتصوير الحالة الحالية للبحث على مسار السكك الحديدية. باستخدام برنامج عارض VOS ، تم إجراء التحليل باستخدام موقع Web of Science من خلال النظر في الدراسة السابقة التي أجريت على المستوى الفرعي لمسار السكك الحديدية. باستخدام ميزة تحليل التكرار للكلمات الرئيسية ، نظرت هذه الدراسة في تكرار حدوث الكلمة الرئيسية ، "الطبقة السفلية" استنادًا إلى إجمالي 456 منشورًا مع "تصنيف فرعي" في الكلمات الرئيسية أو الملخص أو العنوان ، حددت نتيجة البحث بنجاح ثلاث مجموعات باستخدام طريقة التحليل العنقودي. تم استخدام تحليل انفجار الاقتباسات في الدراسة لفحص اتجاه النمو في مجال الطبقة التحتية وإظهار كيف تغير البحث على مسار السكك الحديدية بمرور الوقت. من أجل تصنيف الوضع الحالي والاتجاه التصاعدي في مسار السكك الحديدية بشكل أكثر دقة ، تعتبر هذه الدراسة مميزة من حيث أنها تعطي القارئ معلومات كاملة عن مجموعة الأبحاث السابقة حول تحقيقات الطبقة السفلية. أظهرت مراجعة الدراسات السابقة أن تثبيت الطبقة السفلية سيعزز الصفات الهندسية ، حيث كانت نسبة 10٪ من محتوى الأسمنت للطبقة التحتية للسكك الحديدية هي نسبة مثالية لبعض انواع التربة.

الكلمات الدالة: التحليل السينتومتري ، مسار السكة الحديد ، برنامج VOS.

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